LIBRORY, GZ 20 DEC 1

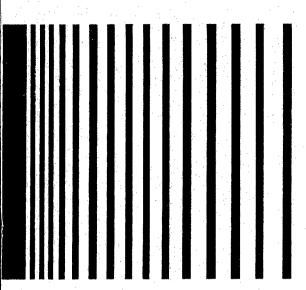
AD A 062673

VOLUME 10, NO. 12

DECEMBER 1978

TECHNICALISTAN

1868



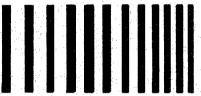
THE SHOCK AND VIBRATION DIGEST

A PUBLICATION OF THE SHOCK AND VIBRATION INFORMATION CENTER NAVAL RESEARCH LABORATORY WASHINGTON, D.C.

Best Available Copy



THE UNDER
SECRETARY
OF DEFENSE
FOR RESEARCH
AND
ENGINEERING



2004 0204 153

Approved for public release; distribution unlimited.

ANUZZY

THE SHOCK AND VIBRATION DIGEST

Volume 10 No. 12 December 1978

STAFF

EDITORIAL ADVISOR:

Henry C. Pusey

TECHNICAL EDITOR:

Ronald L. Eshleman

EDITOR:

Judith Nagle-Eshleman

RESEARCH EDITOR:

Milda Tamulionis

PRODUCTION AND SECRETARIAL:

Valda L. Liesz Martha N. Moss

BOARD OF EDITORS

R. Belsheim W.D. Pilkey
R.L. Bort A. Semmelink
J.D.C. Crisp E. Sevin
C.L. Dym J.G. Showalter
D.J. Johns R.A. Skop
G.H. Klein C.B. Smith

K.E. McKee J.A. Macinante C.T. Morrow J.T. Oden J.C. Snowdon R.H. Volin H. von Gierke E.E. Ungar

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman Vibration Institute Suite 206 101 West 55th Street Clarendon Hills, Illinois 60514

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of \$60.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendar year, beginning with the January issue. Back issues are available by volume (12 issues) for \$15.00. Orders may be forwarded at any time, in any form, to SVIC, Code 8404, Naval Research Laboratory, Washington, D.C., 20375. Issuance of this periodical is approved in accordance with the Department of the Navy Publications and Printing Regulations, NAVEXOS P.35

A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

Code 8404 Naval Research Laboratory Washington, D.C. 20375

> Henry C. Pusey Director

Rudolph H. Volin

J. Gordan Showalter

Barbara Szymanski

Carol Healey

DIRECTOR NOTES

This issue marks the end of a decade of publication of this **DIGEST**. During that time we have seen a number of changes in style and content. These changes have been introduced in part to reflect changing technological emphasis, but mostly to serve the informtion needs of the reader more effectively. The indications are that we have been at least partially successful in our efforts, since your response as readers has been generally favorable. In spite of this, we are well aware that there is always room for improvement. I look forward to a flow of constructive suggestions during the coming year. Whenever possible we will use those suggestions to advantage.

We have not been without our problems. The cost of preparing and distributing the **DIGEST** has increased markedly. We have therefore been required to increase the subscription price to one hundred dollars for the coming year for domestic delivery. Our foreign subscriptions are increased accordingly. It is my expectation that the readers will continue to find the **DIGEST** a prudent investment. Wisely purchased, information is still one of the cheaper commodities on today's market.

During the coming year, we at SVIC plan to issue some interesting publications. I am pleased to announce the first of these, "An International Survey of Shock and Vibration Technology," which will be available for distribution early next year. This report may well be the first of its kind. It is a very broad survey of the complete shock and vibration technology from an international viewpoint. A more complete announcement, along with price, is expected to be given in the January **DIGEST.** Other publications will be announced as they are about to become available.

The encouragement of the shock and vibration community over our many years of service has been gratifying. I look upon 1979 as a new and exciting year of challenge. With your continued support, we will meet that challenge.

H.C.P.

Best Available Copy

EDITORS RATTLE SPACE

THE ADVANCE OF TECHNOLOGY

This issue of the DIGEST marks the end of ten years of publication. During this time the abstracts of almost 20,000 papers, reports, and theses have been published. In addition, more than 200 feature and review articles have appeared. It is an appropriate time to pause and reflect upon the focus of these technological advances -- that is, are they concerned mostly with solving problems or with understanding basic phenomena and environments in vibration and shock?

The abstracts of the past ten years indicate that problems are being studied in ever greater detail but that there has been little accomplished in understanding basic phenomena or developing new techniques. In my opinion this trend is a result of the evaluation of the digital computer as a practical tool for solving engineering problems. In fact the major advances in shock and vibration technology have been in the electronics area -- digital computers for mathematical computation, data handling, and data analysis; and instrumentation for measurement, data analysis, and data display.

The digital computer stimulated work aimed at perfecting numerical methods. For example, the finite element method was developed for solving practical engineering problems in machines and structures. This method has been extended to many physical problems by the development of specific "elements" to represent its physical behavior. The numerical methods used to manipulate equations are thus a by-product of finite element work. Developments of the past ten years have provided the tools for solving most dynamics problems.

The second major area of technological advancement has to do with measurement and data processing. New high response sensors, including proximity probes and accelerometers, allow measurement of vibration and shock phenomena in all frequency ranges. These devices have greatly simplified measurement and made it less of an art. The fast Fourier analyzers have advanced data processing far beyond our expectations. All of this technology is applicable to solving current problems.

What about the advances in the next ten years? In my opinion they will involve digital computers — the development of more practical minicomputers and desk computers. Not only computation will be done on the minicomputer but also much data processing for machine monitoring and diagnostics. Research in understanding basic phenomena is lagging and will continue to do so. Evolution of technology to solve practical problems has been adequate, but it has tended to create an atmosphere in which no one is interested in understanding basic physics other than that absolutely necessary to solve a problem.

R.L.E.

SHOCK AND VIBRATION ANALYSIS USING FINITE ELEMENT TECHNIQUES

T.V. Seshadri*

Abstract - This paper reviews current state of the art in shock and vibration analyses using finite element techniques. The development of a total finite element model using a combination of analytical and experimental techniques is described.

The finite element technique consists of dividing a continuum into a number of discrete elements and imposing conditions (force and displacement compatibilities) at points shared by the elements. These points are called joints or nodes. The increasing use of finite element techniques is largely due to the advancement in sophisticated digital computers. Several finite element codes are available from various sources. Most of these codes use the so-called stiffness method as opposed to the flexibility method.

In the stiffness method, the matrix equation for static force is written as

$$\{F\} = [K] \{x\} \tag{1}$$

where

By setting {x} equal to unity the stiffness matrix represents the force required to cause unit displacement.

For a uniform bar with two joints at each end, as shown in Figure 1, the stiffness matrix can be written as

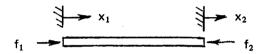


Figure 1. Uniform Bar with Two Nodes

$$[K] = \frac{EA}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$
 (2)

The stiffness matrix can be obtained by assuming a unit displacement in one degree of freedom (keeping all other displacements zero) and finding the force required to cause that unit displacement. Several textbooks on finite element method discuss in detail the calculation of stiffness matrices. The fundamentals have been explained thoroughly [1].

In dynamic analysis, two additional terms - mass and damping matrices -- are needed. The mass matrix can be found in different ways. For example, if the mass m for a uniform bar is lumped at the two nodes (Fig. 2) the mass matrix becomes

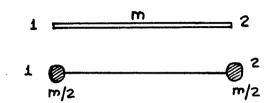


Figure 2. Lumped Mass of Uniform Bar

$$[M] = \begin{bmatrix} m/2 & 0 \\ 0 & m/2 \end{bmatrix}$$
 (3)

If the bar is divided into two elements with three nodes or joints, the lumped mass assumption yields a mass matrix

$$[M] = \begin{bmatrix} m/3 & 0 & 0 \\ 0 & m/3 & 0 \\ 0 & 0 & m/3 \end{bmatrix}$$
 (4)

Thus the lumped mass approach always gives a diagonal mass matrix. A diagonal matrix is one in which elements other than the main diagonal are zero. Such a matrix has several important advantages; computer dynamic analysis involves reducing non-diagonal matrices into diagonal ones. The lumped mass approach is not accurate, however, and the structure may have to be divided into a large

^{*}Fruehauf Corporation, Detroit, Michigan

number of elements to yield reasonable results.

Another method for finding the mass matrix is the consistent mass approach, so called because the mass matrix is derived using the same displacement function as the stiffness. Take, for example, the longitudinal bar; using a consistent mass the mass matrix becomes

$$[M] = \begin{bmatrix} m/3 & m/6 \\ m/6 & m/3 \end{bmatrix}$$
 (5)

This is a non-diagonal matrix and is a better representation of the actual mass distribution than a diagonal matrix. The mass matrices obtained either by lumped or consistent mass are independent of frequency.

Yet another method, called distributed mass, uses exact mathematical expressions for mass distribution. The method yields better results, but the mass and stiffness matrices are functions of frequency. They will therefore involve considerable computer costs and are thus not economical.

The general dynamic equations of motion for an n degree of freedom system in matrix form is

[M]
$$\{\ddot{x}\} + [C] \{\dot{x}\} + [K] \{x\} = \{f(t)\}\$$
 (6)

The solution techniques depend on the nature of f(t). The techniques have been described in detail [1]. Some particulars of those techniques are described below.

FREE VIBRATION OR MODAL ANALYSIS

Before describing the solution techniques for free vibration analysis or modal analysis, it is worthwhile to define modal analysis.

The term modal analysis has become especially popular with empirical vibration engineers. Modal analysis, either analytically or empirically, involves finding the natural frequencies and mode shapes of a structure under free-free conditions. (Free-free conditions can be obtained by supporting the structure on very soft springs.) Various types of test equipment are available to determine the modal

properties of a structure. Analytical modal analysis is discussed below; empirical modal analysis is also briefly explained.

The undamped free vibration equation of a system, using lumped or consistent mass, will be

[M]
$$\{\ddot{x}\} + [K] \{x\} = 0$$
 (7)

using harmonic response

$$\{x\} = \{X\}e^{j\omega t} \tag{8}$$

the matrix equation becomes

$$(-\omega^2[M] + [K]) \{x\} = 0$$
 (9)

For non-trivial solution of equation (9), the condition to be satisfied is that the determinant should vanish.

$$-\omega^{2}[M] + [K]| = 0$$
 (10)

This is called an eigenvalue problem; the vector $\{X\}$ associated with each frequency ω -- called the eigenvector -- is the mode shape.

Several solution techniques are available, the most common of which are determinant tracking, the Jacobi method, the Givens method, and the Householder method. In the determinant tracking method the value of the determinant in equation (10) is calculated for several trial frequencies. When there is a change in sign of the determinant, the determinant is recalculated using a new trial frequency until a specified tolerance level is reached. This method will work well except in some cases with closely spaced natural frequencies (Fig. 3).

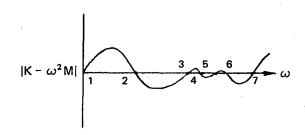


Figure 3. Determinant Tracking Method

One or two roots between 4.5, and 6 may be missed. This difficulty is eliminated by using the Sturm sequence property, which determines the number of roots below any frequency. Actually, the determinant equation (10) is a polynomial equation, and the number of real roots between any two numbers. which are not roots, can be found. The method involves tri-diagonalization of the matrix ([K] - ω^2 [M]); i.e., maximum non-zero terms in a row is 3, one diagonal and two adjacent terms. The values of several pre-defined expressions are calculated. and the sign changes are noted. For example, if N(a) is the number of sign changes for value 'a' and N(b) is the number of sign changes for value 'b', the number of real roots between 'a' and 'b' is N(a)-N(b). Therefore, closely spaced roots cannot be missed. However, the Sturm sequence does not recognize multiple or repeated roots.

The Jacobi method involves taking the largest absolute value of the non-diagonal matrix and applying several orthogonal transformations. The product of these transformation matrices reduces the original matrix to a diagonal matrix even if there are multiple roots. The sequence of transformations, sometimes called rotations, is infinite, though convergent, and the sequence can be terminated depending on the required precision. The eigenvalues will be the elements of the diagonalized matrix.

In the method of Givens, a finite sequence of orthogonal transformations is performed, but the original matrix is reduced to a tridiagonal form. A numerical technique is combined with the Sturm sequence property to obtain all the eigenvalues.

The method of Householder also produces a matrix of tri-diagonal form but with an increase in efficiency and economy as compared to Givens method. For an n x n matrix, (n-2) transformations are required although each might involve more calculations than the Givens method.

SUBSTRUCTURING

In complex structures for which the finite element method is used, the number of equations to be solved is large and requires a large computer core. A few years ago Guyan developed a technique -- now known as the Guyan reduction -- to reduce the number of equations by partitioning the stiffness and mass matrices.

For static analysis the matrix equation is

$$\{F\} = [K] \{x\} \tag{11}$$

Expanding [K] into a 2 x 2 matrix

$$\begin{cases} F_1 \\ F_2 \end{cases} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{cases} x_1 \\ x_2 \end{cases}$$
 (12)

$$F_1 = K_{11}x_1 + K_{12}x_2 \tag{13}$$

$$F_2 = K_{21}x_1 + K_{22}x_2 \tag{14}$$

Solving for x₂ in equation (14)

$$x_2 = K_{22}^{-1} (F_2 - K_{21} x_1)$$
 (15)

Substituting this value of x_2 in equation (13)

$$K_{11}X_1 + K_{12}K_{22}^{-1} (F_2 - K_{21}X_1) = F$$
 (16)

$$(K_{11} - K_{12}K_{22}^{-1}K_{21})x_1 = F_1 - K_{12}K_{22}^{-1}F_2$$
 (17)

or

$$[K] * \{x_1\} = \{F^*\}$$
 (18)

where [K] * and {F*} are modified stiffness matrix and force vector respectively

$$[K^*] = K_{11} - K_{12} K_{22}^{-1} K_{21}$$
 (19)

The matrix manipulations, like decomposition or inversion, must be performed on such smaller matrices as K_{11} , K_{12} , or K_{22} . Because computation time is directly proportional to the square of the number of terms in the matrix, the Guyan reduction results in an efficient, economical solution. In the stiffness matrix reduction, equation (19), there is no approximation involved.

The mass matrix can also be reduced in a similar fashion, but some approximation is involved, the effect of which should be negligible in the final results. In dynamic analysis, the reduction technique depends upon retaining a small proportion of the unknown nodal deflections, called masters. The remaining deflections, known as slaves, are reduced

out. Hence the order of the eigenvalue problem is reduced. With a careful choice of masters, the lower natural frequencies are preserved and can be accurately found.

The eigenvalue problem in matrix form is rewritten as

$$\{[K] - \omega^2[M]\}\} = 0$$
 (20)

The matrices in partitioned form are

$$\left(\begin{bmatrix} K_{mm} & K_{ms} \\ K_{sm} & K_{ss} \end{bmatrix} - \omega^2 \begin{bmatrix} M_{mm} & M_{ms} \\ M_{sm} & M_{ss} \end{bmatrix} \right) \begin{pmatrix} X_m \\ X_s \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} (21)$$

 $X_{\mbox{\scriptsize m}}$ and $X_{\mbox{\scriptsize s}}$ are master and slave degrees of freedom respectively.

In order to eliminate the slaves, it has been observed that, for low frequencies, the effects of inertia forces on the slave displacements are small compared with the effects of static forces. Therefore, the inertia forces arising due to the lower row of the mass matrix in the partitioned matrix, equation (21), are ignored. Expand equation (21) with this assumption

$$K_{mm}X_{m} + K_{ms}X_{s} - \omega^{2}M_{mm}X_{m} - \omega^{2}M_{ms}X_{s} = 0$$
(22)

$$K_{sm}X_m + K_{ss}X_s = 0 (23)$$

From equation (23)

$$X_{s} = -K_{ss}^{-1} K_{sm} X_{m}$$
 (24)

Use equation (24)

$$\{X\} = \begin{cases} X_{m} \\ X_{s} \end{cases} = \begin{bmatrix} I \\ -K_{ss}^{-1} K_{sm} \end{bmatrix} \{X_{m}\}$$
 (25)

The kinetic and strain energies in terms of master degrees of freedom system can be written as

strain energy =
$$\frac{1}{2} \left\{ X_m \right\}^T \left[K^* \right] \left\{ X_m \right\}$$
 (26)

kinetic energy =
$$\frac{1}{2}\omega^2 \left\{ X_m \right\}^T [M^*] \left\{ X_m \right\}$$
 (27)

where [K*] and [M*] are reduced stiffness and mass matrices respectively.

Strain energy and potential energy in terms of total degrees of freedom are

strain energy =
$$\frac{1}{2} \{X\}^T [K] \{X\}$$
 (28)

Kinetic energy =
$$\frac{1}{2}\omega^2 \{X\}^T [M] \{X\}$$
 (29)

Substituting equation (25) in equations (28) and (29)

$$[K^*] = K_{mm} - K_{sm} K_{ss}^{-1} K_{ms}$$
 and (30)

$$[M*] = M_{mm} - K_{ss}^{-1} K_{sm} M_{sm} -$$

$$M_{ms} K_{ss}^{-1} K_{sm} + K_{ss}^{-1} K_{sm} M_{ss} K_{ss}^{-1} K_{sm}$$
(31)

There is no approximation involved in equation (30).

But how to select the master degrees of freedom to obtain good accuracy? The criteria for the choice of an automatic master is based on the ratio of $K_{\rm SS}$ to $M_{\rm SS}$ terms. If one slave displacement is desired, the degree of freedom with the largest $K_{\rm SS}$ to $M_{\rm SS}$ ratio should be chosen. This is based on the assumption that mass terms corresponding to slave displacements have a negligible effect on mode shape. The method therefore involves scanning the leading diagonals of the [K] and [M] matrices to find the degrees of freedom that yield highest $K_{\rm SS}$ to $M_{\rm SS}$ ratios. The user then must decide only on the number of automatic masters required.

Substructuring is also useful in the building block approach, in which each component of a structure is separately analyzed and coupled at certain points. These connection points are the dynamic degrees of freedom or the master degrees of freedom. The components in the building block approach can be analyzed either analytically, using finite element techniques, or empirically. Experimental techniques have advanced in the past few years so that dynamic properties can be measured by exciting the structure by impact, or by random or swept sinusoidal loads.

The dynamic characteristics are determined through frequency response and mode shapes of the structure. The frequency response is obtained with a controlled excitation force; both force and response are measured. The response could either be displacement, velocity, or acceleration. Experimental frequency response techniques have reached such a

sophisticated stage mainly because of the algorithm for rapid Fourier Transform, which is commonly known as Fast Fourier Transform, or FFT.

Experimental modal analysis is important when damping is predominant. The analytical finite element method with damping is complex, and such assumptions as proportional damping must be made to include the contributions due to damping. Such an assumption is in general not realistic except in lightly damped structures. For heavily damped structures, the exact modal contribution of damping might be important.

The finite element solution involves considerable clerical work to keep track of the joint co-ordinates and element connectivity. For a large problem checking the geometry of the model will cost more than the actual computer processing! Several graphic techniques are available now. Using these techniques model creation time is considerably improved. Digitizer tablets are available that create a model from a drawing, thereby reducing the burden on the analyst.

Graphic techniques are also available to animate the vibrating shapes of structures. Color coded graphics are also available to plot stresses and strain energy levels.

The finite element technique has been used for structural analysis, and in such other areas as lubrication, fiber industry, panel flutter, and biomechanics. The buckling of structures is also an eigenvalue problem and a technique analogous to that described here has been used. Current extension of the finite element method involves finding the stress intensity factor and notch factor for fatigue and fracture mechanics analyses. Thus the capability for a complete evaluation of the useful life of a product will soon be available at the drawing stage, given the typical dynamic environment of the product and a finite element dynamic analysis.

REFERENCES

 Seshadri, T.V., "Shock and Vibration Analyses Using Finite Element Techniques," Shock Vib. Dig. (July 1975).

- 2. Meirovitch, L., Elements of Vibration Analysis, McGraw Hill (1975).
- 3. Rodrigues, J.S., "Node Numbering Optimization in Structural Analysis," ASCE J. Struc. Div., 101 (ST2), p 361 (Feb 1975).
- Grooms, H.R. and Rowe, J., "Substructuring and Conditioning," ASCE J. Struc. Div., 103 (ST3), p 507 (Mar 1977).
- Fawzy, I., "A Theorem on the Free Vibration of Damped Systems," J. Appl. Mech., Trans. ASME, p 132 (Mar 1977).
- 6. Guyan, R.J., "Reduction of Stiffness and Mass Matrices," AIAA J., 3 (2), p 380 (1965).
- Tolani, S.K. and Rocke, R.D., "Modal Truncation of Substructures Used in Free Vibration Analysis," ASME Paper No. 75-DET-82.
- 8. Henshell, R.D. and Ong, J.H., "Automatic Masters for Eigenvalue Extraction," Intl. J. Earthquake Engr. Struc. Dynam., 3, p 375 (1975).
- 9. DAGS Manual, Structural Dynamics Research Corporation, Cincinnati (May 1977).
- Hooker, R.J. and O'Brien, D.J., "Natural Frequencies of Box-Type Structures by a Finite Element Method," J. Appl. Mech., Trans. ASME, p 363 (June 1974).
- Meirovitch, L., "A Stationarity Principle for the Eigenvalue Problem for Rotating Structures," AIAA J., 14 (10), p 1387 (Oct 1976).
- Chen, J.C. and Wada, B.K., "Matrix Perturbation for Structural Dynamic Analysis," AIAA J., 15 (8), p 1095 (Aug 1977).
- 13. Hasselman, T.K., "Damping Synthesis from Substructure Tests," AIAA J., 14 (10), p 1409 (Oct 1976).
- 14. Beliveau, J.-G., "Eigenrelations in Structural Dynamics," AIAA J., 15 (7), p 1039 (July 1977)
- 15. Rock, T. and Hinton, E., "Free Vibration and

- Transient Response of Thick and Thin Plates Using the Finite Element Method," Intl. J. Earthquake Engr. Struc. Dynam., 3, p 51 (1974).
- Mayes, R.L. and Mowbray, N.A., "The Effect of Coulomb Damping on Multidegree of Freedom Elastic Structures," Intl. J. Earthquake Engr. Struc. Dynam., 3, p 275 (1975).
- 17. Laurenson, R.M., "Modal Analysis of Rotating Flexible Structures," AIAA J., 14 (10), p 1444 (Oct 1976).
- Hasselman, T.K., "Modal Coupling in Lightly Damped Structures," AIAA J., <u>14</u> (11), p 1627 (Nov 1976).
- 19. Ojalvo, I.U., Austin, F., and Levy, A., "Iterative Analysis Method for Structural Components with Diverse Stiffnesses," AIAA J., 14 (9), p 1219 (Sept 1976).
- Cronin, D.L., "Approximation for Determining Harmonically Excited Response of Nonclassically Damped Systems," J. Engr. Indus., Trans. ASME, p 43 (Feb 1976).
- Nelson, H.D. and McVaugh, J.M., "The Dynamics of Rotor-Bearing Systems Using Finite Elements," J. Engr. Indus., Trans. ASME, p 593 (May 1976).
- 22. Nagarajan, S. and Popov, E.P., "Non-linear Finite Element Dynamic Analysis of Axi-symmetric Solids," Intl. J. Earthquake Engr. Struc. Dynam., 3, p 385 (1975).
- 23. Thomas, J. and Abbas, B.A.H., "Dynamic Stability of Timoshenko Beams by Finite Element Method," J. Engr. Indus., Trans. ASME, p 1145 (Nov 1976).
- Sweet, A.L., Genin, J., and Mlakar, P.F., "Determination of Column-Buckling Criteria from Vibratory Data," Exptl. Mech., p 385 (Oct 1977).
- Gibson, R.F. and Plunkett, R., "A Forced-Vibration Technique for Measurement of Material Damping," Exptl. Mech., p 297 (Aug 1977).

- Halvorsen, W.G. and Brown, D.L., "Impulse Technique for Structural Frequency Response Testing," S/V, Sound Vib., p 8 (Nov 1977).
- 27. Russell, R.H. and Deel, J.C., "Modal Analysis: Trouble-Shooting to Product Design," S/V, Sound Vib., p 22 (Nov 1977).
- 28. "Equipment, Simple and Sophisticated, Helps Pin-Point Harmful Vibrations," Product Engr., (N.Y.), p 49 (Mar 1977).
- 29. Taylor, J.E., "Scaling a Discrete Structural Model to Match Measured Modal Frequencies," AIAA J., p 1647 (Nov 1977).
- Klosterman, A.L. and McClelland, W.A., "Combining Experimental and Analytical Techniques for Dynamic System Analysis," 1973 Tokyo Seminar on Finite Element Analysis (Nov 1973).
- Klosterman, A.L., McClelland, W.A., and Sherlock, J.E., "Dynamic Simulation of Complex Systems Utilizing Experimental and Analytical Techniques," ASME Paper No. 75-WA/Aero-9.
- 32. Klosterman, A.L. and Zimmerman, R., "Modal Survey Activity Via Frequency Response Functions," SAE Paper No. 750168.
- 33. Brigham, E.O., <u>The Fast Fourier Transform</u>, Prentice-Hall (1974).
- Aguiar, A.A., "Applications of Computer Graphics to Automotive Structural Analysis," SAE Paper No. 760182.
- 35. Ladd, H.E., "Mechanism Design Using Animation," J. Engr. Indus., Trans. ASME, p 1324 (Nov 1976).
- Angus, G.D., Parmater, J.Q., and Smith, R.L., "Integration of Interactive Graphics into the Design Process," Fourth Annual Graphics Conf., Engr. Soc. Detroit (Apr 1978).
- 37. Mei, C., "A Finite Element Approach for Non-Linear Panel Flutter," AIAA J., 15 (8), p 1107 (Aug 1977).
- 38. Singh, D.V., Sinhasan, R., and Ghai, R.C.,

- "Static and Dynamic Analysis of Capillary Compensated Hydrostatic Journal Bearings by Finite Element Method," J. Lubric. Tech., Trans. ASME, p 478 (Oct 1977).
- Eidelberg, B.E. and Booker, J.F., "Application of Finite Element Methods to Lubrication: Squeeze Films between Porous Surfaces," J. Lubric. Tech., Trans. ASME, p 175 (Jan 1976).
- 40. Willis, T. and Sheth, B., "An Application of the Finite Element Method to EHD Lubrication," ASLE Trans., 20 (4), p 340 (1976).
- 41. Kiparissides, C. and Vlachopoulous, J., "Finite Element Analysis of Calendering," Polymer Engr. and Sci., <u>16</u> (10), p 712 (Oct 1976).

LITERATURE REVIEW survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field

This issue of the DIGEST contains review articles on aeroacoustics and plate vibrations. Dr. Arndt, Director of the St. Anthony Falls Hydraulic Laboratory, has prepared an interesting sketch on aeroacoustics: jet noise and noise from rotating blades.

Dr. Leissa of Ohio State University has prepared a review of the literature on recent research in plate vibrations. Dr. Leissa is the author of the popular monographs on plate and shell vibrations.

A SKETCH OF AEROACOUSTICS

R.E.A. Arndt*

Abstract - This article reviews the state of the art in aeroacoustics. Aircraft noise sources are summarized. Two major noise sources -- jet noise and noise from rotating blades -- are described in detail. Research trends are mentioned.

The general problems of noise reduction and acoustic fatigue fall within the general area of a new and challenging field called aeroacoustics -- an amalgam of aerodynamics and acoustics. Both are well developed disciplines; only in recent years has the aerodynamicist had much to do with acoustics and the acoustician with aerodynamics. The birth of aeroacoustics is often attributed to the classical publications of Lighthill [1] in 1952 and 1954. The theoretician would say that the propagation of low to medium intensity acoustical waves is but one example of a weakly perturbed compressible flow and that many features of high intensity acoustic waves or nonlinear acoustics are also known to the aerodynamicist. However, in practice, the acoustician is generally concerned with linear phenomena and with such properties of non-dispersive waves as transmission, reflection, refraction, and defraction. The aerodynamicist has been concerned mostly with such nonlinear phenomena as convective acceleration of fluid particles over bodies, vorticity, and turbulence in different types of flow fields. Classical acoustics is concerned with sound from such external forces as a loudspeaker, a vibrating violin or a blacksmith pounding an anvil with a hammer. Aeroacoustics is concerned with sound produced by the motion of fluids or bodies in the atmosphere and by such chemical processes as the combustion of jet fuel. Thus the intensity of sound from a given source is determined from aerodynamic considerations. The study of sound propagation is based on the principles of classical acoustics.

The discovery that the flow of a fluid or air over a body can create sound dates from the classical work of Strouhal [2] published in 1878. The foundations of propeller and helicopter rotor noise were laid down more recently. Gutin [3] demonstrated

in the late 1940s that the steady blade loads (relative to the propeller) associated with a thrusting rotor can produce sound. At about the same time Yudin [4] provided a way to study the noise due to unsteady propeller blade forces associated with vortex shedding phenomena. The classic work of Lighthill [1] provided the first firm theoretical basis for the study of noise due to a flowing medium in the absence of boundaries. Lighthill's work follows traditional lines in that he lumped the aerodynamics of the problem into an equivalent acoustic source strength. Crow [5] published an attempt to provide an integrated theory of jet noise in 1970. He formulated the aerodynamic sound emission problem in terms of matched asymptotic expansions; the inner solution provided a physical description of a compressible vortical flow (turbulence), and the outer solution consisted of a weakly perturbed wave-like motion (the acoustic radiation). In my opinion this paper is the basis for a unified approach to aeroacoustics and perhaps indicates the direction in which the future of aeroacoustics could be structured.

There is a need to train people to work in aeroacoustics. Active work dates back only about 25 years, yet the field has a firm theoretical foundation. The major developments are associated with aircraft noise, but possibilities in other fields are almost limitless. It is the aim of this paper to review the state of the art in aeroacoustics.

AIRCRAFT NOISE SOURCES

A typical jet engine is shown in Figure 1. Several internal rotating devices - fan, compressor, and turbine - generate noise that propagates from the inlet and discharge ducts. The burning of fuel in the engine is also a noise source, as are the discharges of hot gases from the turbine and of cold air from the fan that provide the engine thrust. The identification of a noise source and the study of noise propagation are complex. Various noise sources can contribute to the total noise problem. As a jet aircraft approaches

^{*}Professor and Director, St. Anthony Falls Hydraulic Laboratory, Mississippi River at 3rd Avenue S.E., University of Minnesota, Minneapolis, Minnesota 55414

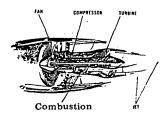


Figure 1. Jet Engine Noise Sources (After Sofrin)

an observer, the noise signature is dominated by noise propagating out the inlet (Fig. 2). As the aircraft passes overhead, the noise that has propated out of the discharge ducts predominates; finally, as the aircraft leaves the observation point, the low frequency rumble of the jet exhaust dominates. Thus, many noise sources must be considered simultaneously in considering ways to decrease the overall noise level for a given aircraft.

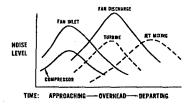


Figure 2. Flyover Noise History for a Jet Transport

Multiple noise sources are evident in Figure 3 which is a spectrum of noise from a typical helicopter. Both pure tone noise and broadband noise are present, and such components as the main rotor, tail rotor, power plant, and gearbox contribute to the noise signature.

Jet Noise

One major aircraft noise source is the fluctuating pressure field generated by the mixing of a high velocity jet with the atmosphere. Jet noise studies focus on the precise nature of the turbulence created by the mixing process, the exact nature of the sound generating mechanism -- including whether or not the major source involves the formation of a turbulent eddy or its decay -- whether or not some orderly structure in a turbulent jet tends to enhance the acoustic efficiency of turbulent noise sources, and the sound due to the interaction of turbulence

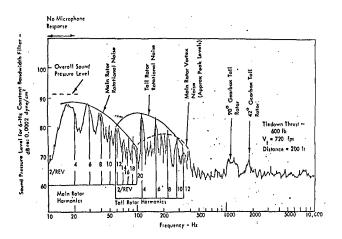


Figure 3. UH-1A External Noise Spectrum

and the shock structure in a turbulent jet. Jet suppressor technology has not yet been developed to the point that a rational approach to jet noise suppression is possible.

Much of what is known about jet noise has been deduced from a few basic principles that are briefly reviewed below. The Lighthill acoustic analogy was developed from the conservation of mass and momentum in a general fluid flow.

$$\frac{\partial^2 \rho}{\partial t^2} - a_0^2 \frac{\partial^2 \rho}{\partial x_i \partial x_i} = \frac{\partial^2 T_{ij}}{\partial x_i \partial x_i}$$
(1)

$$T_{ij} \cong \rho_{O} u_{i} u_{j} \tag{2}$$

In the equations ρ is the density, and a_0 the acoustic velocity in the undisturbed medium. A formal solution to equation (1) is given by

$$p' = \frac{1}{4\pi a_0^2} \frac{x_i x_j}{|x|^3} \int_{\nabla} \frac{\partial^2 T_{ij}}{\partial t^2} [\underline{y}, t'] dy$$
 (3)

$$t' = t - \frac{r}{a_0}, \quad r = |x|$$
 (4)

In equation (3) p' is the pressure level at x due to a distribution of sound sources in the volume ∇ , and the position of each sound source is y. Although the actual solution of equation (3) requires extensive measurement of the turbulent velocity field, Lighthill and others have suggested that many of the general features of jet noise can be inferred from

similarity principles.

Assume that the total sound at a given point is made up of the contribution of many uncorrelated sound sources within the jet. The sound from a volume of turbulence is then given by equation (5).

$$p' \cong \frac{x_i x_j V_e}{4\pi a_0^2 |x_i|^3} \quad \ddot{T}_{ij} (t - \frac{r}{a_0})$$
 (5)

 V_{e} is the volume over which a given sound source is correlated. The intensity I and total radiated power W are related to the square of the acoustic pressure.

$$I \equiv \frac{p'^2}{\rho_0 a_0} \tag{6}$$

$$W \sim 1|x|^2 \tag{7}$$

The total power radiated per unit volume of turbulence is therefore given by

$$\frac{W}{Vol} = \frac{V_e \omega^4 T_{ij}^2}{\rho_0 a_0^5}$$
 (8)

Equation (8) assumes that differentiation with respect to time is proportional to a characteristic frequency ω . The variation of radiated acoustic power, the sound power per unit slice of jet, and the spectral characteristics of jet noise can be estimated from equation (8).

Detailed information is needed on the flow structure of turbulent jets; e.g., estimates for T_{ii} and V_e imply the need for turbulence measurements. In addition, two-point correlations are needed to estimate Ve, which can be said to be proportional to the cube of the integral scale. Figure 4 shows that a jet contains several different regions of flow. As the flow leaves the nozzle, a region of intense turbulent mixing is formed. The interchange in momentum between the core and the mixing regions decreases the core region. At about four diameters from the nozzle the potential core ceases to exist; further mixing shifts the region of maximum turbulence intensity toward the centerline. In the fully developed region the profiles of mean and fluctuating velocities are similar; the profiles attain a maximum at the jet centerline.

Figure 5 shows the results of correlation studies with a hot wire anemometer in the mixing zone of a jet. The data are plotted in terms of contours of constant

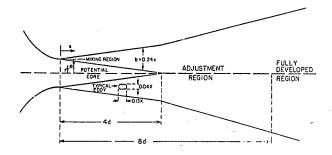


Figure 4. Flow Structure of Turbulent Jet

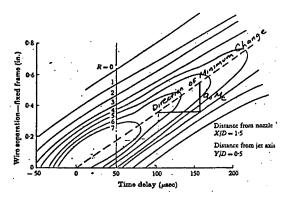


Figure 5. Correlation Studies in a Turbulent Jet [6]

correlation. A minimum change in correlation occurs in a certain direction in the space-time plane. The slope of this line is the convective speed of the eddies or acoustic sources in a jet because an observer moving with this speed sees the true time rate of change of the turbulent structure. It has been shown [6] that an autocorrelation in this frame of reference can be approximated by

$$R_{\tau} \sim \exp\left[-\frac{\tau}{T}\right] \tag{9}$$

$$T \cong \frac{4.5}{\frac{\partial U}{\partial r}} \tag{10}$$

The turbulence intensity in the region is proportional to the mean shear $\frac{\partial \overline{u}}{\partial r}$ and the scale of the turbulence L.

$$u' \cong 0.2 \frac{\partial \overline{u}}{\partial r} \quad L \tag{11}$$

Furthermore, the product of Tu' is proportional to the scale of the turbulence.

$$Tu' \cong 0.9L$$
 (12)

Thus the characteristic frequency ω in equation (8) is given by

$$\omega \sim \frac{1}{T} = 1.1 \frac{u'}{L} \tag{13}$$

and in the mixing region

$$\frac{2\pi\omega d}{U_{i}} = 0.53 \left(\frac{x}{d}\right)^{-1}$$
 (14)

A summary of measured and estimated turbulence data and the acoustic properties that can be inferred from these data is presented in Table 1. The estimates of acoustic properties are based on equation (8) and the following assumptions. The effective volume is assumed proportional to the cube of the eddy scale.

$$V_e \sim L^3 \tag{15}$$

Similarly the source strength Tii is given by

$$T_{ij} \sim \rho_O u'^2 \tag{16}$$

The sound power per unit slice of jet is estimated from

$$\frac{dW}{dx} \cong \frac{W}{Vol} \frac{Vol}{Slice}$$
 (17)

where

$$\frac{\text{Vol}}{\text{Slice}} \sim d^2 \left(\frac{x}{d}\right)$$
 mixing region (18)

$$\sim d^2 \left(\frac{x}{d}\right)^2$$
 fully developed (19)

In the adjustment region the estimate is

$$\frac{\text{Vol}}{\text{Slice}} \sim d^2 \left(\frac{x}{d}\right)^{3/2} \tag{20}$$

Table 1. Measured Functional Properties of Jet Turbulence and Inferred Acoustic Characteristics

Flow Property/Region	Mixing	Adjustment (estimated)	Fully Developed	
<u>u'</u> V _j	const	$(\frac{x}{d})^{-1/2}$	$(\frac{\mathbf{x}}{\mathbf{d}})^{-1}$	
L d	<u>x</u> d	$(\frac{x}{d})^{1/2}$	<u>x</u>	
$\frac{{a_o}^5 d}{{\rho_o} U_j^8} \frac{W}{Vol}$	$\left(\frac{x}{d}\right)^{-1}$	$\left(\frac{x}{d}\right)^{-2/3}$	$(\frac{x}{d})^{-9}$	
$\frac{a_0^5}{\rho_0 v_j^8 d} \frac{dw}{dx}$	const	$(\frac{x}{d})^{-3}$	$\left(\frac{\mathbf{x}}{\mathbf{d}}\right)^{-7}$	
$\frac{a_o^5}{\rho_o v_j^8 d^2} s$	$\sim (\frac{\omega d}{U_{j}})^{-2}$	<u>ωd</u> Ūj	$\left(\frac{\omega d}{U_{\mathbf{j}}}\right)^{2}$	

Similarly the spectrum of the acoustic signal is estimated from

$$S(\omega) \equiv \left| \frac{dW}{d\omega} \right| \tag{21}$$

and

$$\frac{dW}{d\omega} = \frac{dW}{dx} \frac{1}{\frac{d\omega}{dx}}$$
 (22)

The total radiated power of a jet is given by

$$W = \int_{0}^{\infty} \frac{dW}{dx} dx$$
 (23)

which is

$$W \sim \frac{\rho_0 U_j^{8} d^2}{a_0^{5}}$$
 (24)

From a design point of view equation (24) is probably the most significant result of the jet noise theory. The inherent advantages of the fan jet engine are apparent from this equation: significant noise reduction is possible at a given thrust level by moving larger quantities of air at a lower jet velocity. Propulsive efficiency is also increased.

Solutions of equation (24) are compared with data measured for several variables in Figure 6. The agreement is remarkable. The trend of noise spectra is compared with experimental results in Figure 7; the expected results are again remarkably reliable.

From equation (24) it can be shown that acoustic efficiency varies with the Mach number to the fifth power. There is a limit, however to acoustic efficiency. The intensity of acoustic radiation is altered by the effects of convection.

$$1 \sim \frac{\rho_0 U_j^8}{a_0^5 r^2} = \frac{1}{c^5}$$
 (25)

C is a convection factor

$$C = \left\{ (1 - M_{c} \cos \theta)^{2} + \frac{\omega^{2} L^{2}}{\pi a_{o}^{2}} \right\}^{1/2}$$
 (26)

Convection Eddy
Effect Decay
(Frozen
Turbulence)

As the eddy approaches supersonic speed, Mach waves form at an angle to the flow direction.

$$\theta_{\rm c} = \cos^{-1} \frac{1}{M_{\rm c}}$$
 $M_{\rm c} > 1$ (27)

 $\rm M_C$ is the convection Mach number. The implication of equation (27) is that very intense sound is focused at an angle $\theta_{\rm C}$ to the jet. According to classical theory the sound would be very intense if the eddy were not decaying. Hence, when the eddies are convected supersonically, the convection factor C is not zero at $\theta_{\rm C}$ but rather

$$C \simeq \frac{\omega L}{a_0}$$
, $\theta = \cos^{-1} \frac{1}{M_C}$ (28)

The acoustic intensity is thus

$$I \sim \frac{\rho_0 \cup_{j}^8}{a_0^5 r^2} = \frac{1}{(\frac{\omega L}{a_0})^5}$$
 (29)

Because $\omega L \sim U_j$, the intensity is

$$I \sim \frac{\rho_0 U_j^3}{r^2} \tag{30}$$

Equation (30) implies that acoustic efficiency is independent of Mach number. This result is in close agreement with observations of rocket noise.

Noise From Rotating Blades

One of the most common ways to impart or extract energy from a moving fluid is by aerodynamic lift in a rotating device. The most common devices in aerospace are propellers, helicopter rotors, fans, compressors, and turbines; all are important noise sources (see Table 2).

According to the theory of noise generation, the two fundamental types of noise sources are a dipole due to aerodynamic loading and a monopole due to the displacement that occurs when a blade of finite thickness is moving through the air. Turbulence created by the movement of the blades is an additional noise source. The major noise source common to all rotating devices, blade loading, is shown systematically in Figure 8. The relationship of the pressure field at x, due to a dipole at y moving relative to the observer with velocity a_0M_r , is

$$P' = \frac{x_i - y_i}{4\pi a_0 r^2 (1 - M_r)^2} \left\{ \frac{\partial \{F_i\}}{\partial t} + \frac{\{F_i\}}{1 - M_r} \frac{\partial M_r}{\partial t} \right\}$$
(31)

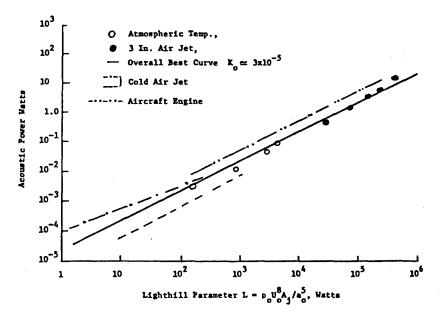


Figure 6. Acoustic Power as a Function of Lighthill Parameter

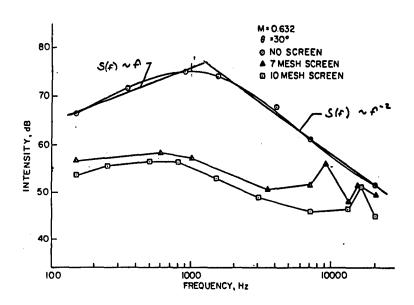
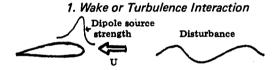


Figure 7. Frequency Spectrum of Jet Noise

Table 2. Typical Rotating Devices and Their Operating Conditions

Component	В	Chord Length (ft)	D(ft)	Tip Speed (ft/sec)	НР
Propellers	2-6	0.3-1	5-12	500-1000	50-5,000
Helicopter Rotors	2-6	0.3-2	5-70	500-900	50-10,000
Fans, Compressors Turbines	15-80	0.05-0.5	0.5-9	500–2000	50-50,000
Space System Impellers	2-10	0.02-0.05	0.05	200–400	0.1-1

Two Types:



a) Wake Interaction - Enhancement of Harmonic Content

b) Turbulence or Non-Stationary Flow Distortions - can be in harmonics of blade passing frequency or broad band

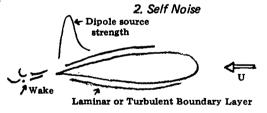


Figure 8. Schematic of Rotor Noise Blade Loading

Two contributors to the noise field are unsteady loads on the blade and acceleration of a steady load. Hence, if a propeller is operating with steady velocity in completely quiescent air, the blade load is steady and the first term in the brackets in equation (31) is zero. Only the steady load contributes to the sound field and is completely dependent on the centrifugal acceleration. Consideration of this

case resulted in the classical equation relating the noise level in each blade passing harmonic mB to the number of blades B, the thrust T, and the torque Q [3].

$$\langle SP_{mB} \rangle = \frac{mBN}{\sqrt{2Ra_0}} \left[T \cos \delta - \frac{Q}{r_e M_e} \right] J_{mB}$$

$$(mBM_e \cos \delta) \qquad (32)$$

$$M_e = \frac{2\pi N r_e}{a_0}$$
 (33)

N is the rotational speed, and δ is the angle the observer makes with the thrust line. Equation (32) is useful in design for determining the relative effects of blade loading, the number of blades, and the rotational speed on the noise signature. All harmonics of pressure are due to a pressure field that rotates at the basic rotor speed N. Unsteadiness has a significant effect. For example, if a flow distortion results in an unsteady blade loading at a specific blade position, the pressure level is considerably enhanced in the higher harmonics (mB>1). The problem is further complicated by the fact that the pressure level in each harmonic is made up of an infinite number of modes rotating with speeds

$$\omega_{\rm m} = \frac{2\pi \rm mBN}{\rm mB \pm s} \tag{34}$$

Here s corresponds to the harmonic of blade loading

$$L = L_0 + \sum_{s=1}^{\infty} L_s \cos(s\psi - \theta_s)$$
 (35)

L is the lift on each blade, and ψ is the blade position. A typical example of this type of loading is the effect of forward flight on a helicopter rotor; the velocity relative to the advancing blade is higher than that relative to the retreating blade. Another example is a compressor in which the rotor blades repeatedly slice through the wakes of the upstream stator vanes. The effects of such flow unsteadiness are shown in Figure 9.

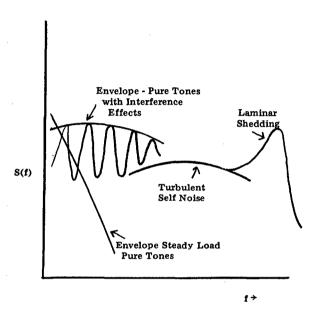


Figure 9. Schematic of Rotor Noise Spectrum

Changes in rotating modes are important when a rotor is placed in a duct — the situation in a jet engine. According to theory a rotating pressure field propagates only in a thin annular duct of radius $r_{\rm O}$ if the rotational Mach number is greater than unity.

$$\frac{2\pi Nr_{O}}{a_{O}} > 1 \tag{36}$$

Thus, no noise propagates from a rotor rotating with subsonic tip speed in a circular duct if no flow distortion is occurring. If a rotor with B blades is operating behind a stator with V blades, an infinite number of rotational modes exist in each harmonic mB. Each mode rotates with a speed given by equation (34); in this case s is kV, k being any integer.

$$\omega_{\pm k} = \frac{2\pi mBN}{mB\pm kV}$$
 (37)

The noise level in any harmonic is thus critically dependent on the number of stator and rotor vanes. The worst situation is a device with an equal number of rotor and stator vanes because, regardless of the tip speed, each harmonic of a blade passing frequency will propagate. As shown by equation (37), an integer k always exists that makes ω infinite. This very important point has resulted in the removal of the fan inlet guide vanes in the newest jet engines.

TRENDS

This review of jet and fan noise has described some of the factors that control the acoustic output from various aircraft components. It should be pointed out that most of the dramatic advances in aircraft noise control thus far have been based on a few relatively simple facts that have emerged from a considerable research effort.

However, as is true of any aspect of noise control, as one noise source is diminished, another becomes prominent. Efforts are being made to understand combustion noise; the propagation of internal noise sources through complex ducts, rotors, and guide vanes; the effect of rotation on the decay of rotor and stator wakes so that spacing for noise control can be optimal; and the noise due to turbulence ingestion either in the boundary layer along the wall of the inlet duct or in the atmosphere. Considerable effort is being expended to clarify the performance of acoustic liners in the presence of flow. The liner itself is a source of flow noise, and recent investigations have shown that the acoustic impedance of the liner is affected by the structure of the flow over the liner.

It should be mentioned that even if jet engine noise were completely masked, a typical jet transport would still be extremely noisy. Figure 10 shows that airframe noise is significant. If further improvements in jet engine noise control technology become a reality, airframe noise will become a significant problem, especially if noise control regulations are made more strict. A myriad of aeroacoustic noise sources are associated with airframe noise -- boundary layer noise, interaction of boundary layer turbulence with the trailing edges of wings and control surfaces, interaction of acoustic modes and shear layer instabilities at cut-outs such as wheel wells, and vortex shedding noise.

SLIDE 8 AIRFRAME AERODYNAMIC NOISE AT FAR-36 LANDING APPROACH CONDITIONS VS GROSS WEIGHT AT 150 KNOTS APPROACH SPEED C. = 1.36, W./S = 103 PSF, ALTITUDE = 370 FT

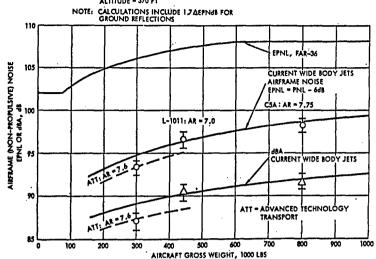


Figure 10. Predicted Airframe Noise

In addition, STOL and VTOL vehicles have special noise sources; e.g., blown flaps and jet flaps. It is of interest that these aeroacoustic problems touch on many areas in basic fluid mechanics as well as acoustics. For example, many recently published basic turbulence research results began as aeroacoustic problems.

Thus, although significant advances have been made in aircraft noise control, much remains to be done in the way of fundamental research, design, development of test facilities, development of sophisticated data processing techniques, and even in optimizing flight operational procedures for minimizing noise while maintaining a high degree of safety and performance.

ACKNOWLEDGMENTS

The preparation of this paper was partially supported by NASA under Grant No. NGR39-009-007 under the direct administration of Mr. James Stone. The visits to European research centers during the sabbatical leave of the author were made possible by a NATO Senior Scientist Fellowship Award and through support from the Office of Naval Research/London.

REFERENCES

- Lighthill, M.J., Proc. Royal Soc. (London), <u>211</u>, Ser. A, pp 564-587 (1952) and <u>222</u>, pp 1-32 (1954).
- Strouhal, V., Ann Phys. Chemie, New Ser., <u>5</u>, pp 216-251 (1878).
- 3. Gutin, L., NACA TM 1195 (1948).
- 4. Yudin, E.Y., NACA TM 1136 (1947).
- Crow, S.C., Studies in Appl. Math., MIT, <u>XLIX</u>, pp 21-44 (1970).
- Davies et al, J. Fluid Mech., <u>15</u>, pp 337-367 (1963).

RECENT RESEARCH IN PLATE VIBRATIONS. 1973 - 1976: COMPLICATING EFFECTS

A.W. Leissa*

This paper is a review of literature dealing with the complicating effects of free, undamped vibrations of plates that appeared from 1973-1975 and in part of 1976. Recent research dealing with the complicating effects of anisotropy, in-plane forces, variable thickness, surrounding media, large deflections, shear deformation, rotary inertia, and nonhomogeneity (including layered plates) is summarized.

A previous paper [1] reviewed the recent literature of free vibrations of plates according to classical theory. Classical theory is governed by the equation of motion

$$D\nabla^4 w + \rho \frac{\partial^2 w}{\partial t^2} = 0$$
 (1)

That survey dealt with literature published from the beginning of 1973 through part of 1976; the present paper continues the survey and includes eight complicating effects, each of which requires generalization of equation (1) and increases the difficulty in obtaining analytical solutions for free vibration frequencies, nodal patterns, and mode shapes.

ANISOTROPIC PLATES

For plates having general anisotropy the term $D\nabla^4 w$ in equation (1) must be greatly expanded. Isotropic materials that have only two independent elastic coefficients -- usually taken as E (Young's modulus) and v (Poisson's ratio) -- can be combined into a single flexural rigidity parameter, D. Definition of a generally anisotropic plate requires five independent rigidity parameters. Because of the number of additional parameters and terms required in equation (1), as well as further complications owing to coupling between derivatives, no results for the vibration of generally anisotropic plates are known to the author.

Orthotropic plates require the definition of three independent rigidity parameters. Thus, thorough

numerical studies require the variation of two parameters that are ratios of flexural rigidities. Furthermore, orthotropy can be defined with respect to various coordinate systems: the two most commonly used are polar and rectangular. Some recent work has also been done with skew orthotropy.

Polar Orthotropy

In the case of polar orthotropy equation (1) generalizes to

$$D_{r} \frac{\partial^{4} w}{\partial r^{4}} + 2 \frac{D_{r\theta}}{r^{2}} \frac{\partial^{4} w}{\partial r^{2} \partial \theta^{2}} + \frac{D_{\theta}}{r^{4}} \frac{\partial^{4} w}{\partial \theta^{4}} + 2 \frac{D_{r}}{r} \frac{\partial^{3} w}{\partial r^{3}}$$

$$-2\frac{\mathsf{D}_{\mathsf{r}\theta}}{\mathsf{r}^3}\frac{\partial^3\mathsf{w}}{\partial\mathsf{r}\partial\theta^2} - \frac{\mathsf{D}_{\theta}}{\mathsf{r}^2}\frac{\partial^2\mathsf{w}}{\partial\mathsf{r}^2} + \frac{2}{\mathsf{r}^4}\left(\mathsf{D}_{\theta} + \mathsf{D}_{\mathsf{r}\theta}\right)\frac{\partial^2\mathsf{w}}{\partial\theta^2}$$

$$+\frac{D_{\theta}}{r^3}\frac{\partial w}{\partial r} + \rho \frac{\partial^2 w}{\partial t^2} = 0 \tag{2}$$

 D_r , D_θ , and $D_{r\theta}$ are the appropriate flexural rigidity parameters [2]. Equation (2) permits separation of variables.

Axisymmetric vibrations of clamped circular plates have been analyzed [3]. Particular attention was given to the questionable meaning of polar orthotropy at the origin (r=0).

Ramaiah and Kumar [4, 5] made a thorough study of annular plates. The Ritz method was used with algebraic polynomial deflection functions [4] to obtain frequency parameters for all nine combinations of simple boundary conditions for various ratios of flexural rigidities and of boundary radii (b/a). Simple approximate formulas expressed the orthotropic frequencies in terms of flexural rigidity ratios and the frequencies of corresponding modes in the axisymmetric case. A simplified method based upon the assumption that the radial bending moment is small at a nodal circle [5] was shown to be especially useful for estimating frequencies of modes having a large number of nodal circles.

Orthotropic circular plates having concentric iso-

^{*}Professor of Engineering Mechanics, Ohio State University, Columbus, Ohio

tropic cores have been analyzed [6,7]. Axisymmetric frequencies were given for cases having clamped and simply supported boundaries. Annular corrugated disks have been represented by orthotropic plates [8] for the theoretical analysis of the case in which the outside boundary is free and the inside one clamped; theoretical results were compared with experimental ones.

Rubin [9] used the Frobenius method to study annular sector plates with radial edges simply supported. Numerical results were presented for a case with the inner boundary clamped and the outer one free. Vibrations of circular polar orthotropic plates have also been studied [10-13].

Rectangular Orthotropy

For rectangular orthotropy equation (1) becomes

$$D_{X} \frac{\partial^{4} w}{\partial x^{4}} + 2D_{XY} \frac{\partial^{4} w}{\partial x^{2} \partial y^{2}} + D_{Y} \frac{\partial^{4} w}{\partial y^{4}} + \rho \frac{\partial^{4} w}{\partial t^{2}} = 0 \quad (3)$$

 ${\rm D_{X}},~{\rm D_{Y}},$ and ${\rm D_{XY}}$ are the appropriate flexural rigidity parameters [2] .

The six cases of rectangular plates having two opposite edges simply supported have straightforward, exact solutions [2]. This procedure has been used [14-18] as a basis for comparison of approximate methods. Aksu and Ali [15] demonstrated a finite difference method using an unequal interval formulation; an optimum interval variation parameter was determined. Vijakumar [16] applied Bolotin's asymptotic method to obtain numerical results for five of the six cases. A finite-strip-difference technique was utilized and discussed [17, 18].

The rectangular orthotropic plate clamped on all edges has been studied [19-22]. Bauer and Reiss [19] used the perturbation method; the isotropic solution supplied the leading term in the perturbation expansion. King and Lin [22] used Bolotin's method to obtain results for the CFCF plate as well.

For plates of other shapes with rectangular orthotropy, an interesting reduction method has been demonstrated [23]. A frequency of one plate was estimated from that of another having a different shape. The method was demonstrated for the clamp-

ed ellipse (derived from results for the circle) and for the simply supported skew (parallelogram) plate (derived from the simply supported isotropic rectangular plate).

Maurizi and Laura [24] investigated rectangular plates having rectangular axes of orthotropy rotated through an angle ϕ with respect to the plate edges. The Galerkin method with algebraic polynomials was used to derive formulas for the first four frequencies of a clamped rectangular plate. Curves were plotted for an example representing a unidirectional boron-epoxy material.

Srinivasan and Munaswamy [25] studied the problem of the parallelogram plate having four free edges and supported at four interior points. The problem was solved by means of skew finite strips; extensive numerical results showing frequency parameters and mode shapes were presented [25].

Orthotropic parallelogram plates have also been treated [26], as have trapezoids [27]. Other references deal with free vibration of plates having rectangular orthotropy [28-30].

Skew Orthotropy

The case of a material with principal axes of orthotropy that are straight but not orthogonal has been investigated by Nair and Durvasula [31]. They used the Ritz method and presented extensive numerical results for square and skew plates having various combinations of boundary conditions. Orthotropic rhombic plates have also been studied [32].

IN-PLANE FORCES

The presence of in-plane forces during the vibration of a plate requires additional terms in equation (2); they are second derivatives of w. If the in-plane forces are constant with respect to the space variables, the additional terms will have constant coefficients. For example, one important case is that of hydrostatic normal stress — i.e., constant normal stress in all directions — for which equation (1) becomes

$$D\nabla^4 w - N\nabla^2 w + \rho \frac{\partial^2 w}{\partial t^2} = 0$$
 (4)

N is the constant tensile in-plane force per unit

length of boundary. Generally speaking, tensile in-plane forces increase the vibration frequencies, whereas compressive forces decrease them. Reduction of a frequency to zero yields a buckling load for the plate.

Circular Plates

Considerable recent research on the circular plate subjected to hydrostatic loading and supported elastically on the boundary has been done [33-37]. Both translational and rotational edge springs were considered [36]. A concentrated mass was added at the center [37]. Extensive results were presented [34].

The rotation about the polar axis as a cause of variable in-plane stresses, as well as thermal in-plane stresses, have been studied [38, 39]. Nieh and Note [38] compared experimental results with theoretical ones.

Some recent work has dealt with the annular plate [40-43]. Rosen and Libai [40, 41] studied the case in which the outer edge is simply supported and uniformly compressed, and the inner one is free. Simple one-term Rayleigh solutions were derived for the vibration modes having no internal nodal circles. Numerical results were compared with experimental ones. Loh [42] treated the case when the inner edge is simply supported and uniformly compressed, and the outer one is either simply supported or free and is free of in-plane loads. The disk is simultaneously spinning about its polar axis. The rotating disk has been studied [43, 44].

Rectangular Plates

It can be shown [2] that in rectangular coordinates the effects of in-plane forces are accounted for by adding the terms

$$N_{x} \frac{\partial^{2} w}{\partial x^{2}} + 2 N_{xy} \frac{\partial^{2} w}{\partial x \partial y} + N_{y} \frac{\partial^{2} w}{\partial y^{2}}$$
 (5)

to the right-hand sides of equations (1) or (3), where the N's are the positive in-plane normal and shearing forces per unit length (either constant or variable). For the special case of hydrostatic loading equation (4) results.

For N_x and N_y constant, and $N_{xy} = 0$, the six cases of rectangular plates having two opposite edges simply supported have straightforward, exact solutions [2]. Cases of this type have been studied [14, 45, 46].

Dickinson [47] analyzed the orthotropic, clamped, square plate subjected to hydrostatic loading by means of Bolotin's method. Plates having two parallel edges clamped and the other two free have been discussed [48]. The effects of residual stresses upon frequencies of a free plate with a weld longitudinally along its center have been examined [49]. Extensive numerical results for simply supported plates having different rotational springs along various edges and subjected to biaxial in-plane loads (N_X and N_Y) have been obtained by Laura and Romanelli [50]. Other references deal with rectangular planes having in-plane loads [51-53].

Other Shapes

Jones and Mazumdar [54] addressed the problem of the hydrostatically loaded, elliptical plate having clamped or simply supported edges. Numerical results were given for a wide range of loading parameters and for various aspect ratios. Natural frequencies of plates having elliptical holes have been studied [55]. Analytical results from the Galerkin method were compared with experimental ones. Rhombic (parallelogram) and trapezoidal plates have been treated, [32] and [27] respectively.

PLATES WITH VARIABLE THICKNESS

For plates having variable thickness the flexural rigidity (D) is no longer constant, and several terms containing variable coefficients must be added to equation (1) [2].

Circular Plates

Solid circular plates have been discussed [43, 56-59]. Kirkhope and Wilson [43] used annular finite elements to analyze free plates with parabolic thickness variation. They obtained extensive results for modes having 0 to 6 nodal diameters and 0 to 3 nodal circles. Polar orthotropic disks having exponential thickness variation were examined by Ghosh [56]. The axisymmetric modes of plates having linear and parabolic thickness variation have also been analyzed [57], as have plates with a single step in thickness [58].

Annular circular plates with linear thickness varia-

tions have been considered [60-63]. Ramaiah and Vijayakumar [60] made a thorough study for thickness variations, both increasing and decreasing with the radius; all nine possible combinations of simple edge conditions; various taper ratios and boundary radii ratios; and 0 to 2 nodal diameters. They used the Ritz method with nine trial functions in the radial direction, which should be sufficient to give accurate results. Soni and Amba-Rao [61, 62] examined the axisymmetric modes of plates having the inner edge clamped, the outer edge being clamped, simply supported, or free. The finite element method was used [63] to obtain the first two frequencies for the nine combinations of edge conditions except free-free.

The effects of in-plane forces acting on tapered circular plates have been investigated [39, 64].

Rectangular Plates

Rectangular plates having linear thickness variation along one of the directions parallel to an edge have been considered [65-72]. Eastep [65] used the perturbation method on the simply supported square plate. Simply supported orthotropic plates were studied by Sakata [66] for various taper ratios, aspect ratios, and ratios of orthotropic constants. Plates having two opposite sides simply supported and the other two either simply supported or clamped and subjected to thermal gradients were examined by Rao and Satyanarayana [67].

Other thickness variations have been considered [71-76]. Rectangular plates having the sides y = 0. b simply supported, and parabolic thickness variation in the x-direction have been studied [71]. The infinite strip of parabolic thickness variation in the transverse direction and its edges simply supported and/or clamped was treated by Tomar and Gupta [73]. Soni and Rao [74] analyzed plates having y = 0, b simply supported, x = 0 clamped, and x = aclamped, simply supported or free, with exponential thickness variation in the x direction, for various taper ratios and aspect ratios. Wertz [72] used the perturbation method to investigate square, simply supported plates having linear thickness variation in two directions simultaneously (maximum or minimum thickness at center) and compared the results with finite difference, finite element, and experimental results. He also treated one case involving stepped thickness. Olhoff [75] considered the

problem of determining the plate thickness variation that maximizes the fundamental frequency for a given volume. The finite difference method was used on the resulting nonlinear partial differential equations.

Other Shapes

Chopra and Durvasula [77] addressed the problem of the rhombic plate with linearly varying thickness using the Ritz method with beam functions. Numerical results were obtained for the case when the opposite sides are simply supported and the other two are clamped and for various skew angles and taper ratios. Dokainish and Kumar [26] considered the completely clamped parallelogram having linearly varying thickness and orthotropic elastic constants in terms of orthogonal axes. The first two frequencies were found for various values of aspect ratio, skew angle, and taper ratio. Other results for the clamped parallelogram plate having linear thickness variation are also available [78]. Bailey and Greetham [27] examined trapezoidal plates having variable thickness with the additional complicating effects of thermal stress and orthotropy.

THE EFFECTS OF SURROUNDING MEDIA

Analytical solutions of free vibration problems are almost always based upon the assumption that the vibrating body is in a vacuum. Real problems and experimental simulations usually take place in air. Some references [2] have been made that deal with this difference, which can be significant. However, apparently no recent research has been done on this topic.

LARGE DEFLECTIONS

The term large deflections here refers to transverse deflections sufficiently large to cause additional stiffening of the plate due to membrane stretching at the midplane. This effect is usually significant for maximum deflections on the order of the plate thickness or more, and depends considerably on edge conditions. The simple governing equation of motion must be replaced by two coupled, nonlinear differential equations that include the effects of membrane stretching. A hypothesis due to Berger [79] simplifies the equations somewhat and is often

used. Much recent research has been done for large deflection vibrations of plates; brief descriptions are given below.

Circular Plates

Solid circular plates have been treated [80-88], including clamped [80-84], simply supported [80-83], elastically supported [85], and discontinuous [86, 87] boundary conditions. In addition, the effects of an elastic foundation [81] and of polar orthotropic material [82, 83, 87] have been studied. Notable for its good bibliography, especially from other countries, is the work of Sathymoorthy and Pandalai [88]. Vendham [84] made an interesting critical study of the Berger equations and compared them with the von Kármán equations; he found that the former do not give consistently accurate results and may even yield different mode shapes.

Annular plates have been considered [88-92]. Sandman and Walker [89] presented experimental results. Huang [90] included a concentric isotropic core. In one case [91] the annulus having its inner boundary clamped and outer free was considered for constant thickness and for thickness partly constant and partly linearly tapered.

Rectangular Plates

Large amplitude oscillations of rectangular plates have been widely studied [68, 81, 83, 88, 93-105]. Simply supported [81, 84, 93-97], clamped [81, 84, 93-95], and other plates having combinations of boundary conditions [68, 95, 98] have been investigated; it must be remembered that the in-plane, as well as transverse, edge constraint conditions must be defined in each problem. In addition, elastic edge constraints [99, 100], discontinuous edge conditions [101] -- square plates having portions of their boundaries clamped, other portions simply supported -- a concentrated mass [102], an elastic foundation [81, 103], orthotropic material [94, 104], and variable thickness [68] have been studied. Ramachandran and Reddy [68] were able to establish bounds on the nonlinear fundamental frequency.

Other Shapes

Parallelogram plates have been analyzed [78, 88, 106-108] for various edge conditions, including the effects of orthotropy [78, 107] and variable thickness [78]. Various shapes of triangular plates were also examined [84, 88, 93, 109, 110], including

the effects of orthotropy [110] and an elastic foundation [81, 109]. Elliptic plates have also been studied [88]. Datta [81] presented an interesting method using conformal mapping, along with the Galerkin procedure, which can accommodate a wide variety of shapes.

Other references deal with large amplitude vibrations of plates [111-115].

SHEAR DEFORMATION AND ROTARY INERTIA

For relatively thick plates (h/I > 1/20, where h is the plate thickness and I is an average length in its plane) the effects of shear deformation and rotary inertia become significant. The inclusion of shear deformation in the analysis of plate vibrations requires considerable generalization of equations (1). It is replaced by a sixth order set of equations; the most widely used in dynamic problems is that derived by Mindlin [116]. For this sixth order theory, three boundary conditions must be specified along an edge.

Circular Plates

The vibrations of thick, solid, circular plates have been studied [117-121]. Chandrasekaran and Kunukkasseril [117] obtained results for the first 20 modes for four types of clamped and supported edge conditions. They compared the results of classical and sixth order theories. Isotropic plates having clamped or supported edges have also been investigated [118, 119]. The effects of orthotropy have been included [120, 121]. Soni and Amba-Rao [120] presented numerical results for the first five axisymmetric modes of an orthotropic plate having linear thickness variation.

Thick, annular plates have been considered [122, 123]. Rao and Prasad [122] reported extensive numerical results for the nine combinations of usual boundary conditions (clamped, simply supported, or free) for inner and outer circular boundaries. Results were reported for various ratios of thickness and of inner to outer radii.

Rectangular Plates

Triangular and quadrilateral finite elements have been used [124] to analyze simply supported and clamped rectangular plates. Finite elements have also been used [119]. The first 13 frequencies of a simply supported rectangular plate having a thickness ratio of 1/10 and an aspect ratio of $\sqrt{2}$ have been reported [125]. Orthotropic effects were also studied. The effects of in-plane stress have been included [126, 127]. Reismann and Tendorf [126] presented results for the simply supported plate having a thickness ratio of 1/10 and an aspect ratio of $\sqrt{2}$ for the case of uniform in-plane stress (tension or compression) in one direction. Brunelle and Robertson [127] considered the effects of both axial stress N_X and axial moment M_X, with both bending and extensional deformation, upon a simply supported plate. In another paper [128] they treated transversely isotropic plates having the same types of in-plane stress. The effects of large deflections upon the vibration of thick plates have been investigated [129]. Results were given for the simply supported square.

Other work deals with thick plates [130-133]. Vibrations of thick orthotropic plates have been used to determine elastic properties experimentally [130].

NONHOMOGENEOUS PLATES

Material properties of a plate can vary with its length coordinates (say x or y) or with its thickness coordinate (z). The properties can vary continuously or in a step-wise manner. Examples of the former include materials that can vary widely in modulus of elasticity naturally (e.g., rubber, styrofoam) or as a result of severe thermal gradients [67]. Examples of the latter are layered plates, including those made of fibrous composite layers, which are of great importance in advanced plate design.

For layered plates the differential equation of motion (1) must be generalized by a piecewise integration of the forces and moments over the thickness of the plate, and, unless the layer arrangement is symmetrical with respect to the midplane of the plate, bending and stretching of the midplane are coupled during plate deformation. It has been shown by Reissner and Stavsky [134], Whitney and Leissa [135], and many others that the effect of the coupling is often significant with respect to vibration frequencies.

General problems of vibrating nonhomogeneous plates [67, 136-138] include the effects of materials

with continuously varying properties. Many recent publications have dealt with vibrations of layered (laminated) plates [119, 139-175]. The effects of initial, in-plane forces have been treated [139-143], and nonlinear (large deflection) vibrations have been studied [144-148]. Bert [149] wrote an excellent survey paper on the vibrations of layered plates, with special emphasis on the effects of damping.

SUMMARY

In the previous paper of this series [1] it was shown that considerable research in the vibration of plates is governed by classical plate theory. It was conjectured that probably more research on classical plate vibrations has been done and reported since the beginning of 1966 than in all time previous [2].

REFERENCES

- Leissa, A.W., "Recent Research in Plate Vibrations, 1973-1976: Classical Theory," Shock Vib. Dig., 9 (10), pp 13-14 (Oct 1977).
- Leissa, A.W., "Vibration of Plates," NASA SP-160, U.S. Govt. Printing Office (1969).
- 3. Prathap, G. and Varadan, T.K., "Axisymmetric Vibrations of Polar Orthotropic Circular Plates," AIAA J., 14 (11), pp 1639-1640 (1976).
- Ramaiah, G.K. and Vijayakumar, K., "Natural Frequencies of Polar Orthotropic Annular Plates," J. Sound Vib., <u>26</u> (4), pp 517-531 (1973).
- Ramaiah, G.F. and Vijayakumar, K., "Estimation of Higher Natural Frequencies of Polar Orthotropic Plates," J. Sound Vib., 32 (2), pp 265-278 (1974).
- Woo, H.K., Kirmser, P.G., and Huang, C.L., "Vibration of Orthotropic Circular Plates with Concentric Isotropic Core," AIAA J., 11, pp 1421-1422 (1973).
- Rao, K.S. and Ganapathi, K., "Vibration of Cylindrically Orthotropic Circular Plates,"

- J. Sound Vib., 36 (3), pp 433-434 (1974).
- Rao, B.V.A. and Rama Bhat, B., "Vibrations of an Orthotropic Annular Disc Supported at the Inside Edge," J. Sound Vib., <u>42</u> (4), pp 510-514 (1975).
- Rubin, C., "Vibrating Modes for Simply Supported Polar-Orthotropic Sector Plates," J. Acoust. Soc. Amer., <u>58</u> (4), pp 841-845 (1975).
- Padovan, J. and Lestingi, J., "Natural Frequencies of Monoclinic Circular Plates," J. Acoust. Soc. Amer., <u>55</u> (4), pp 874-876 (1974).
- 11. Imer, S. and Zimmermann, P., "Free Vibration of Polar-Orthotropic Disks," Ing. Arch., 42 (6), pp 395-410 (1973).
- Pardoen, G.C., "Vibration and Buckling Analysis of Axisymmetric Polar Orthotropic Circular Plates," Computers and Struc., <u>4</u> (5), pp 951-960 (1974).
- 13. Zimmermann, P. and Imer, S., "Free Vibrations of a Polar Orthotropic Annular Plate," (In German), Zeitschrift f. Angewandte Math. und Mech., 54 (6), pp 366-369 (1974).
- Soni, S.R. and Rao, C.L.A., "Vibrations of Orthotropic Rectangular Plates under In-Plane Forces," Computers and Struc., <u>4</u> (5), pp 1105-1115 (1974).
- Aksu, G. and Ali, R., "Prediction of Dynamic Characteristics of Orthotropic Plates by Finite Difference Unequal Interval Formulation," J. Sound Vib., 35 (1), pp 119-128 (1974).
- Vijakumar, K., "Natural Frequencies of Rectangular Orthotropic Plates with a Pair of Parallel Edges Simply Supported," J. Sound Vib., 35 (3), pp 379-394 (1974).
- Sundarajan, C. and Reddy, D.V., "Finite Strip-Difference Calculus Technique for Plate Vibration Problems," Intl. J. Solids Struc., 11 (4), pp 425-435 (1975).
- 18. Lowrey, M.J., "Discussion of: Finite Strip-Difference Calculus Technique for Plate Vibra-

- tion Problems," Intl. J. Solids Struc., <u>12</u>, p 391 (1976).
- 19. Bauer, L. and Reiss, E.L., "Flexural Vibrations of Clamped Orthotropic Plates," J. Acoust. Soc. Amer., 53 (5), pp 1360-1364 (1973).
- 20. Elishakoff, I.B., "Vibration Analysis of Clamped Square Orthotropic Plate," AIAA J., 12 (7), pp 921-923 (1974).
- 21. Ramachandra Rao, B.S., Narasimham, G.L., and Gopalacharyulu, S., "Eigenfunction Analysis for Bending of Clamped Rectangular, Orthotropic Plates," Intl. J. Solids Struc., 9 (4), pp 481-493 (1973).
- 22. King, W.W. and Lin, C., "Applications of Bolotin's Method to Vibrations of Plates," AIAA J., 12, pp 399-401 (1974).
- 23. Sakata, T., "A Reduction Method for Problems of Vibration of Orthotropic Plates," J. Sound Vib., 48 (3), pp 405-412 (1976).
- 24. Maurizi, M.J. and Laura, P.A., "Vibration Analysis of Clamped Rectangular Plates of Generalized Orthotropy," J. Sound Vib., 26 (3), pp 299-305 (1973).
- Srinivasan, R.S. and Munaswamy, K., "Frequency Analysis of Skew Orthotropic Point Supported Plates," J. Sound Vib., 39 (2), pp 207-216 (1975).
- Dokainish, M.A. and Kumar, K., "Vibrations of Orthotropic Parallelogramic Plates with Variable Thickness," AIAA J., 11 (12), pp 1618-1621 (1973).
- Bailey, C.D. and Greetham, J.C., "Free Vibrations of Thermally Stressed Orthotropic Plates with Various Boundary Conditions," Ohio State Univ. Res. Foundation NASA-CR-2174 p 101 (1973).
- Aksu, G., "Dynamic Analysis of Orthotropic Plates Using a Finite Difference Formulation," Ph.D. Thesis, Loughborough Univ. (1974).
- 29. Aksu, G. and Ali, R., "Finite Difference For-

- mulation for the Boundary Regions of Orthotropic Plates and Its Application to the Prediction of Their Dynamic Behavior," Dept. of Transport Technology, Loughborough Univ., Tech. Rept. No. TT 7310 (1973).
- Yu, J.C.M. and Foster, W.A., Jr., "Unified Method for Determination of Fundamental Frequency of Orthotropic Plate with Arbitrary Boundary," Developments in Mechanics (Proc. 13th Midwest Mech. Conf., Pittsburgh, PA) 7, pp 721-732 (1973).
- Nair, P.S. and Durvasula, S., "Vibration of Generally Orthotropic Skew Plates," J. Acoust. Soc. Amer., <u>55</u> (5), pp 998-1002 (1974).
- Srinivasan, R.S. and Ramachandran, S.V., "Vibration of Generally Orthotropic Skew Plates," J. Acoust. Soc. Amer., <u>57</u> (5), pp 1113-1118 (1975).
- Laura, P.A.A. and Gelos, R., "Further Results on the Vibration and Stability of a Circular Plate Elastically Restrained Against Rotation," J. Sound Vib., 41 (3), pp 388-390 (1975).
- 34. Laura, P.A.A., Luisoni, L.E., and Arias, A., "Antisymmetric Modes of Vibration of a Circular Plate Elastically Restrained Against Rotation and Subjected to a Hydrostatic State of In-Plane Stress," J. Sound Vib., <u>47</u> (3), pp 433-437 (1976).
- Laura, P.A.A., Diez, L., and Gianetti, C.E., <u>Métodos Approximados en la Mecánica Ap-licada</u>, Patagon, Bahia Blanca, Argentina (1975).
- Laura, P.A.A., Luisoni, L.E., and Lopez, J.J., "A Note on Free and Forced Vibrations of Circular Plates: The Effect of Support Flexibility," J. Sound Vib., 47 (2), pp 287-291 (1976).
- Laura, P.A.A., Arias, A., and Luisoni, L.E., "Fundamental Frequency of Vibration of a Circular Plate Elastically Restrained Against Rotation and Carrying a Concentrated Mass," J. Sound Vib., 45 (2), pp 298-301 (1976).

- 38. Nieh, L.T. and Mote, C.D., Jr., "Vibration and Stability in Thermally Stressed Rotating Disks," Exptl. Mech., <u>15</u> (7), pp 258-264 (1975).
- 39. Ghosh, N.C., "Thermal Effect on Transverse Vibration of Spinning Disk of Variable Thickness," J. Appl. Mech., Trans. ASME, 42 (2), pp 358-362 (1975).
- Rosen, A. and Libai, A., "Stability Behaviour and Vibrations of an Annular Plate Under Uniform Compression," Technion, Israel Inst. of Tech., Haifa, Israel, Dept. Aero Engrg., Rept. No. TAE-229 (1974).
- 41. Rosen, A. and Libai, A., "Transverse Vibrations of Compressed Annular Plates," J. Sound Vib., 40 (1), pp 149-153 (1975).
- 42. Loh, H.C., "Vibration and Stability of a Spinning Annular Plate Reinforced with Edge Beams," Ph.D. Thesis, Univ. Connecticut (1975).
- Kirkhope, J. and Wilson, G.J., "Vibration and Stress Analysis of Thin Rotating Discs Using Annular Finite Elements," J. Sound Vib., 44 (4), pp 461-474 (1976).
- Ghosh, N.C., "Transverse Vibration of Spinning Disk Clamped Partially Between the Hubs of Equal Radii," Czech. J. Phys., B, <u>24</u> (7), pp 781-785 (1974).
- 45. Dokmeci, M.G. and Boley, B.A., "Vibration Analysis of a Rectangular Plate," J. Franklin Inst., 296 (5), pp 305-321 (1973).
- 46. Koshor, B., "On the Natural Frequencies of Transverse Vibrations of an Elastic Plate (with Inplane Forces) Resting on a Winkler Foundation," J. Appl. Mech., Trans. ASME, 40 (2), pp 607-608 (1973).
- Dickinson, S.M., "Bolotin's Method Applied to the Buckling and Lateral Vibration of Stressed Plates," AIAA J., 13 (1), pp 109-110 (1975).
- 48. Bassily, S.F. and Dickinson, S.M., "Corrigen-

- dum: Buckling and Lateral Vibration of Rectangular Plates Subject to Inplane Loads a Ritz Approach," J. Sound Vib., 29 (4), pp 505-508 (1973).
- Porter Goff, R.F.D., "The Effect of Self-Equilibrating Stresses on the Natural Frequencies of a Free-Free Rectangular Plate," J. Sound Vib., 47 (1), pp 85-94 (1976).
- Laura, P.A.A. and Romanelli, E., "Vibrations of Rectangular Plates Elastically Restrained Against Rotation Along All Edges and Subjected to a Biaxial State of Stress," J. Sound Vib., 37 (3), pp 367-377 (1974).
- Kumai, T., "Effect of Edge Thrust on the Natural Frequency of Flexural Vibration of Rectangular Plates," Rept. Res. Inst. for Appl. Mech., 20 (66), pp 73-76 (1973).
- Bassily, S.F. and Dickinson, S.M., "Vibration of Plates Subject to Arbitrary In-Plane Loads -A Perturbation Approach," J. Appl. Mech., Trans. ASME, 40, pp 1023-1028 (1973).
- 53. MacBain, J.Ç., "Vibratory Behavior of Twisted Cantilevered Plates," J. Aircraft, <u>12</u> (4), pp 343-349 (1975).
- Jones, R. and Mazumdar, J., "Transverse Vibration of Elliptic Plates with In-Plane Forces," Proc. Noise, Shock, Vibr. Conf., Monash Univ., Melbourne, Australia, pp 107-112 (1974).
- 55. Datta, P.K. and Carlson, R.L., "Buckling and Vibration of a Thin Tensioned Sheet with an Elliptical Hole," Exptl. Mech., 13 (7), pp 280-286 (1973).
- Ghosh, N.C., "The Vibration of Rotating Aeolotropic Elastic Disk of Variable Thickness," Indian J. Phys. and Proc. Indian Assoc. Cultivation Sci., 47 (11), pp 693-700 (1973).
- Banjaree, M.M., "On the Nonlinear Vibrations of Elastic Circular Plates of Variable Thickness," J. Sound Vib., 47 (3), pp 341-346 (1976).
- 58. Gallego, J.J.A., "Axisymmetric Vibrations of

- Circular Plates with Stepped Thickness," J. Sound Vib., 26 (3), pp 411-416 (1973).
- 59. Chen, S.S.H., "Bending and Vibration of Plates of Variable Thickness," J. Engr. Indus., Trans. ASME, 98 (1), pp 166-170 (1976).
- Ramaiah, G.K. and Vijayakumar, K., "Vibrations of Annular Plates with Linear Thickness Profiles," J. Sound Vib., 40 (2), pp 293-298 (1975).
- Soni, S.R. and Amba-Rao, C.L., "Axisymmetric Vibrations of Annular Plates of Variable Thickness," J. Sound Vib., 38 (4), pp 465-473 (1975).
- 62. Soni, S.R., "Quintic Splines in Vibrations of Nonuniform Annular Plates," Computers and Struc., 4 (6), pp 1269-1279 (1974).
- Raju, I.S., Prakasa Rao, B., and Venkateswara Rao, G., "Axisymmetric Vibrations of Linearly Tapered Annular Plates," J. Sound Vib., 32 (4), pp 507-512 (1974).
- Takahashi, S., Suzuki, K., and Nakamura, Y., "The Vibrations of a Circular Plate with Uniformly Distributed Load Around Its Outer Periphery," Bull. JSME, 16, pp 714-722 (1973).
- 65. Eastep, F.E., "Estimation of the Fundamental Frequency of Beams and Plates with Varying Thickness," AIAA J., 14 (11), pp 1647-1649 (1976).
- 66. Sakata, T., "Natural Frequencies of Orthotropic Plates with Varying Thickness," J. Acoust. Soc. Amer., 60 (4), pp 844-847 (1976).
- Rao, C.K. and Satyanarayana, B., "Effect of Thermal Gradient on Frequencies of Tapered Rectangular Plates," AIAA J., 13 (8), pp 1123-1126 (1975).
- Ramachandran, J. and Reddy, D.V., "Nonlinear Vibrations of Rectangular Plates with Linearly Varying Thickness," Appl. Sci. Res., <u>31</u> (1), pp 67-80 (1975).
- 69. Horwat, J.W., "Experimental Investigation of

- Natural Frequencies of Plates with Variable Thickness," Air Force Inst. Tech., Rept. No. GCE/MC/74-14 (1975).
- Venkateswara Rao, G. and Raju, I.S., "A Comparative Study of Variable and Constant Thickness High Precision Triangular Plate Bending Elements in the Analysis of Variable Thickness Plates," Nucl. Engr. Des., <u>26</u> (2), pp 299-304 (1974).
- 71. Jain, R.K. and Soni, S.R., "Free Vibrations of Rectangular Plates of Parabolically Varying Thickness," Indian J. Pure Appl. Meth., 4, pp 267-277 (1973).
- 72. Wertz, F.H., "Approximate Solutions for the Fundamental Frequency of Square Plates with Variable Thickness," Air Force Inst. Tech., School Engrg., MS Thesis (1974).
- Tomar, J.S. and Gupta, D.C., "Free Vibrations of an Infinite Plate of Parabolically Varying Thickness on Elastic Foundation," J. Sound Vib., 47 (1), pp 143-145 (1976).
- Soni, S.R. and Rao, K.S., "Vibrations of Nonuniform Rectangular Plates: A Spline Technique Method of Solution," J. Sound Vib., 35 (1), pp 35-45 (1974).
- 75. Olhoff, N., "Optimal Design of Vibrating Rectangular Plates," Intl. J. Solids Struc., 10 (1), pp 93-109 (1974).
- 76. Chopra, I., "Vibration of Stepped Thickness Plates," Intl. J. Mech. Sci., <u>16</u> (6), pp 337-344 (1974).
- 77. Chopra, I. and Durvasula, S., "Vibration of Tapered Skew Plates," Revue Roumaine des Sciences Techniques, Serie de Mécanique Appliquée, 18 (5), pp 925-938 (1973).
- Sathyamoorthy, M. and Pandalai, K.A.V., "Large Amplitude Vibration of Variable Thickness Skew Plates," Proc. Noise, Shock, Vibr. Conf., Monash Univ., Melbourne, Australia, pp 99-106 (1974).
- 79. Berger, H.M., "A New Approach to the Analy-

- ses of Large Deflection of Plates," J. Appl. Mech., Trans. ASME, 22 (4), p 465 (1955).
- 80. Ramachandran, J., "Nonlinear Vibrations of Circular Plates with Linearly Varying Thickness," J. Sound Vib., 38 (2), pp 225-232 (1975).
- 81. Datta, S., "Large Amplitude Free Vibrations of Irregular Plates Placed on an Elastic Foundation," Intl. J. Nonlin. Mech., 11 (5), pp 337-345 (1976).
- 82. Pal, M.C., "Static and Dynamic Nonlinear Behavior of Heated Orthotropic Circular Plates," Intl. J. Nonlin. Mech., <u>8</u> (5), pp 489-504 (1973).
- 83. Venkatoswara Rao, G., Kanaka Raju, K., and Raju, I.S., "Finite Element Formulation for Large Amplitude Flexural Vibrations of Beams and Orthotropic Circular Plates," Computers and Struc., 6 (3), pp 169-172 (1976).
- 84. Vendhan, C.P., "A Study of Berger Equations Applied to Non-Linear Vibrations of Elastic Plates," Intl. J. Mech. Sci., 17 (7), pp 461-468 (1975).
- Ramachandran, J., "Large Amplitude Vibrations of Elastically Restrained Circular Plates,"
 J. Acoust. Soc. Amer., <u>55</u> (4), pp 880-882 (1974).
- 86. Ramachandran, J., "Large Amplitude Vibrations of Circular Plates with Mixed Boundary Conditions," Computers and Struc., 4 (4), pp 871-877 (1974).
- 87. Nowinski, J.L., "Some Static and Dynamic Problems Concerning Nonlinear Behavior of Plates and Shallow Shells with Discontinuous Boundary Conditions," Intl. J. Nonlin. Mech., 10 (1), pp 1-14 (1975).
- Sathyamoorthy, M. and Pandalai, K.A.V., "Large Amplitude Vibrations of Certain Deformable Bodies. Part 2: Plates and Shells," J. Aero. Soc. India, 25 (1), pp 1-10 (1973).
- 89. Sandman, B.E. and Walker, H.S., "An Ex-

- perimental Observation in Large Amplitude Plate Vibrations," J. Appl. Mech., Trans. ASME, 40 (2), pp 633-634 (1973).
- 90. Huang, C.-L., "Finite Amplitude Vibrations of an Orthotropic Circular Plate with an Isotropic Core," Intl. J. Nonlin. Mech., <u>8</u> (5), pp 445-457 (1973).
- 91. Huang, C., Woo, H.K., and Walker, H.S., "Non-Linear Flexural Oscillations of a Partially Tapered Annular Plate," Intl. J. Nonlin. Mech., 11 (2), pp 89-97 (1976).
- Huang, C.-L. and Woo, H.K., "Large Oscillations of an Orthotropic Annulus," Developments in Mech. (Proc. 13th Midwest Mech. Conf., Pittsburgh, PA) 7, pp 1027-1039 (1973).
- 93. Vendhan, C.P., "Modal Equations for the Nonlinear Flexural Vibration of Plates," AIAA J., 13 (8), pp 1092-1094 (1975).
- 94. Kanaka Raju, K. and Venkateswara Rao, G., "Non-linear Vibrations of Orthotropic Plates By a Finite Element Method," J. Sound Vib., 48 (2), pp 301-303 (1976).
- 95. Venkateswara Rao, G., Raju, I.S., and Raju, K.K., "A Finite Element Formulation for Large Amplitude Flexural Vibrations of Thin Rectangular Plates," Computers and Struc., 6 (3), pp 163-167 (1976).
- Alekseeva, N.K., "Approximate Method of Determining the Natural Frequencies of a Nonlinear Rectangular Plate," (In Russian), Prikladnaya Mekhanika, 9 (6), pp 68-72 (1973).
- Crawford, J. and Atluri, S., "Nonlinear Vibrations of a Flat Plate with Initial Stresses,"
 J. Sound Vib., 43 (1), pp 117-129 (1975).
- 98. Mei, C., "Finite Element Displacement Method for Large Amplitude Vibrations of Beams and Plates," Computers and Struc., 3, pp 163-174 (1973).
- 99. Ramachandran, J., "Large Amplitude Vibrations of Elastically Restrained Rectangular Plates," J. Appl. Mech., Trans. ASME, 40,

- pp 811-813 (1973).
- Ramachandran, J., "Nonlinear Vibrations of Elastically Restrained Rectangular Orthotropic Plates," Nucl. Engr. Des., 30 (3), pp 402-407 (1974).
- Ramachandran, J., "Large Amplitude Natural Frequencies of Rectangular Plates with Mixed Boundary Conditions," J. Sound Vib., 45 (2), pp 295-297 (1976).
- Ramachandran, J., "Non-Linear Vibrations of Rectangular Plates Carrying a Concentrated Mass," J. Appl. Mech., Trans. ASME, pp 630-632 (1973).
- 103. Kishor, B. and Rao, J.S., "Nonlinear Vibration Analysis of a Rectangular Plate on a Viscoelastic Foundation," Aeronaut. Quart., 25 (1), pp 37-46 (1974).
- 104. Vendhan, C.P. and Das, Y.C., "Application of Rayleigh-Ritz and Galerkin Methods to Nonlinear Vibration of Plates," J. Sound Vib., 39 (2), pp 147-157 (1975).
- 105. Bayles, J.D., Lowery, R.L., and Boyd, D.E., "Nonlinear Vibration of Rectangular Plates," ASCE J. Struc. Div., 99 (ST 5), pp 853-864 (1973).
- 106. Sathyamoorthy, M. and Pandalai, K.A.V., "Vibration of Simply-Supported Clamped Skew Plates at Large Amplitudes," J. Sound Vib., 27 (1), pp 37-46 (1973).
- 107. Sathyamoorthy, M. and Pandalai, K.A.V., "Nonlinear Vibration of Elastic Skew Plates Exhibiting Rectilinear Orthotropy," J. Franklin Inst., 296 (5), pp 359-369 (1973).
- 108. Sathyamoorthy, M. and Pandalai, K.A.V., "Large Amplitude Flexural Vibration of Simply Supported Skew Plates," AIAA J., 11 (9), pp 1279-1282 (1973).
- 109. Sircar, R., "Vibration of Rectilinear Plates on Elastic Foundation at Large Amplitude," Bull. Acad. Polon. Sci., Ser. Sci. Tech., 22 (4), pp 197-203 (1974).

- 110. Vendhan, C.P. and Dhoopar, B.L., "Nonlinear Vibration of Orthotropic Triangular Plates," AIAA J., 11 (5), pp 704-709 (1973).
- Rehfield, L.W., "Nonlinear Free Vibrations of Elastic Structures," Intl. J. Solids Struc., 9 (5), pp 581-590 (1973).
- 112. Westbrook, D.R., "Small Strain Non-Linear Dynamics of Plates," J. Sound Vib., 44 (1), pp 75-82 (1976).
- 113. Harari, A., "Generalized Non-Linear Free Vibration of Prestressed Plates and Shells," Intl. J. Nonlin. Mech., <u>11</u> (3), pp 169-181 (1976).
- 114. Ramachandran, J., "Vibration of Variable Thickness Plates of Large Amplitudes," J. Franklin Inst., 299 (5), p 359 (1975).
- 115. Pandalai, K.A.V., "A General Conclusion Regarding the Large Amplitude Flexural Vibration of Beams and Plates," Israel J. Tech., 11 (5), pp 321-324 (1973).
- 116. Mindlin, R.D., "Influence of Rotary Inertia and Shear on Flexural Motions of Isotropic, Elastic Plates," J. Appl. Mech., Trans. ASME, 18 (1), pp 31-38 (1951).
- 117. Chandrasekaran, K. and Kunukkasseril, V.X., "Forced Axisymmetric Response of Circular Plates," J. Sound Vib., 44 (3), pp 407-417 (1976).
- 118. Chandrasekaran, K. and Kunukkasseril, V.X., "Frequency Spectra of Circular Plates," J. Sound Vib., 33 (3), pp 376-378 (1974).
- 119. Cheung, Y.K. and Kwok, W.L., "Dynamic Analysis of Circular and Sector Thick, Layered Plates," J. Sound Vib., 42 (2), pp 147-158 (1975).
- 120. Soni, S.R. and Amba-Rao, C.L., "On Radially Symmetric Vibrations of Orthotropic Non-Uniform Disks, Including Shear Deformation," J. Sound Vib., 42 (1), pp 57-63 (1975).
- 121. Kunukkasseril, V.X. and Swamidas, A.S.J.,

- "Vibration of Continuous Circular Plates," Intl. J. Solids Struc., 10 (6), pp 603-619 (1974).
- 122. Rao, S.S. and Prasad, A.S., "Vibrations of Annular Plates Including the Effects of Rotary Inertia and Transverse Shear Deformation," J. Sound Vib., 42 (3), pp 305-324 (1975).
- 123. Kanaka Raju, K. and Venkateswara Rao, G., "Axisymmetric Vibrations of Circular Plates Including the Effects of Geometric Nonlinearity, Shear Deformation and Rotary Inertia," J. Sound Vib., 47 (2), pp 179-184 (1976).
- 124. Narayanaswami, R., "New Triangular and Quadrilateral Plate Bending Finite Elements," NASA, Langley Res. Ctr., Rept. No. NASA-TN-D-7407 (1974).
- 125. Rock, T.A. and Hinton, E., "A Finite Element Method for the Free Vibration of Plates Allowing for Transverse Shear Deformation," Computers and Struc., 6 (1), pp 37-44 (1976).
- 126. Reismann, H. and Tendorf, Z.A., "Dynamics of Initially Stressed Plates," J. Appl. Mech., Trans. ASME, 43 (2), pp 304-308 (1976).
- Brunelle, E.J. and Robertson, S.R., "Vibrations of an Initially Stressed Thick Plate,"
 J. Sound Vib., 45 (3), pp 405-416 (1976).
- 128. Brunelle, E.J. and Robertson, S.R., "Initially Stressed Mindlin Plates, AIAA J., 12 (8), pp 1036-1045 (1974).
- 129. Singh, P.N., Sundararajan, V., and Das, Y.C., "Large Amplitude Vibration of Some Moderately Thick Structural Elements," J. Sound Vib., 36 (3), pp 375-387 (1974).
- 130. Ryll-Nardzewski, J., "Application of the Property of Resonant Circular Plates to the Determination of Elastic Constants," (In Polish), Polish Acad. Sci., Warsaw Rept. No. 44/1973 (1973).
- 131. Cornwell, P.E. and Yen, D.H.Y., "Boundary Value Problems in the Improved Theory of Elastic Plates. 1: Existence of Eigenvibra-

- tions for Plates of Arbitrary Shape," SIAM J. Appl. Math., 30 (3), pp 469-482 (1976).
- 132. Rock, T. and Hinton, E., "Free Vibration and Transient Response of Thick and Thin Plates Using the Finite Element Method," Intl. J. Earthquake Engr. Struc. Dynam., 3, pp 51-63 (1974).
- 133. Venkateswara Rao, G., Venkataramana, J., and Prakasa Rao, B., "Vibrations of Thick Plates Using a High Precision Triangular Element," Nucl. Engr. Des., 31 (1), pp 102-105 (1974).
- 134. Reissner, E. and Stavsky, Y., "Bending and Stretching of Certain Types of Heterogeneous Aeolotropic Elastic Plates," J. Appl. Mech., Trans. ASME, 28 (3), pp 402-408 (1961).
- 135. Whitney, J.M. and Leissa, A.W., "Analysis of Heterogeneous Anisotropic Plates," J. Appl. Mech., Trans. ASME, <u>36</u> (2), pp 261-267 (1969).
- 136. Dunninger, D.R., "A Lower Bound for the First Eigenvalue of a Vibrating Nonhomogeneous Plate," Z. Angew. Math. und Phys., 25 (3), pp 422-424 (1974).
- 137. Rao, G.V., Rao, B.P., and Raju, I.S., "Vibrations of Inhomogeneous Thin Plates Using a High Precision Triangular Element," J. Sound Vib., 34 (3), pp 444-445 (1974).
- 138. Komkov, V., "On Lower Bounds of the Natural Frequencies of Inhomogeneous Plates," Quart. Appl. Math., 31 (4), pp 395-401 (1974).
- 139. Biot, M.A., "Buckling and Dynamics of Multi-Layered and Laminated Plates under Initial Stress," Intl. J. Solids Struc., 10 (4), pp 419-451 (1974).
- 140. Bradford, L.G. and Dong, S.B., "Elastodynamic Behavior of Laminated Orthotropic Plates under Initial Stress," Intl. J. Solids Struc., 11 (2), pp 213-230 (1975).
- 141. Chandra, R. and Basava Raja, B., "Large Amplitude Vibration of Cross Ply Laminated

- Composite Plates," Fibre Sci. Tech., <u>8</u>, pp 243-263 (1975).
- 142. Rao, Y.V.K.S. and Sinha, P.K., "Vibrations of Sandwich Plates under Uniaxial Compression," AIAA J., 12 (9), pp 1282-1283 (1974).
- 143. Sinha, P.K. and Rath, A.K., "Frequencies of Free Vibration of Axially Compressed Orthotropic Sandwich Plates," J. Sound Vib., <u>35</u> (4), pp 541-547 (1974).
- 144. Chandra, R., "Nonlinear Vibration of Laminated Composite Panels," M.S. Thesis, Indian Inst. Tech., Madras (1975).
- 145. Chandra, R. and Basava Raju, B., "Large Deflection Vibration of Angle Ply Laminated Plates," J. Sound Vib., 40 (3), pp 393-408 (1975).
- 146. Chandra, R., "Large Deflection Vibration of Cross-Ply Laminated Plates with Certain Edge Conditions," J. Sound Vib., 47 (4), pp 509-514 (1976).
- 147. Shahin, R.M., "Nonlinear Vibrations of Multilayer Sandwich Plates," Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 43, Pt. 2, pp 43-53 (1973).
- 148. Shahin, R.M., "Nonlinear Vibrations of Multilayer Orthotropic Sandwich Plates," J. Sound Vib., 36 (3), pp 361-374 (1974).
- 149. Bert, C.W., "Damping of Composite and Sandwich Panels," Shock Vib. Dig., Part I, 8 (10), pp 37-48 (1976); Part II, 8 (11), pp 15-24 (1976).
- Bert, C.W., "Non-Linear Vibration of a Rectangular Plate Arbitrarily Laminated of Anisotropic Material," J. Appl. Mech., Trans. ASME, 40, pp 452-458 (1973).
- Clary, R.R. and Cooper, P.A., "Vibration Characteristics of Aluminum Plates Reinforced with Boron-Epoxy Composite Material," J. Composite Matl., 7 (3), pp 348-365 (1973).
- 152. Durocher, L.L. and Solecki, R., "Bending and

- Vibration of Transversely Isotropic Two-Layer Plates," AIAA J., 13 (11), pp 1522-1524 (1975).
- 153. Herman, H. and Kirchner, R.P., "Fundamental Frequency Approximation Methods," J. Acoust. Soc. Amer., <u>55</u> (6), pp 1225-1231 (1974).
- 154. Jones, R.M., "Buckling and Vibration of Unsymmetrically Laminated Cross-Ply Rectangular Plates," AIAA J., 11 (12), pp 1626-1632 (1973).
- 155. Kao, W.-T., "Thermally Induced Vibration of Laminated Composite Plates," Ph.D. Thesis, Univ. Nebraska (1973).
- 156. Kao, W.T. and Pao, Y.C., "Thermally-Induced Vibration of Simply Supported Symmetric Cross-Ply Plates," Developments Theor. Appl. Mech. (Proc. 8th SECTAM, Blacksburg, VA) 8, pp 331-348 (1976).
- 157. Khatua, T.P. and Cheung, Y.K., "Bending and Vibration of Multilayer Sandwich Beams and Plates," Intl. J. Numer. Methods Engr., <u>6</u> (1), pp 11-24 (1973).
- 158. Kwok, W.L. and Cheung, Y.K., "Analysis of Circular and Annular Laminated Plates," Proc. Intl. Conf. Finite Element Methods in Engrg., Univ. New South Wales, Sydney, Australia (1974).
- 159. Lin, C.-C., "Free Transverse Vibrations of Rectangular Laminated Plates," Ph.D. Thesis, Georgia Inst. Tech., Atlanta (1973).
- 160. Lin, C.-C. and King, W.W., "Free Transverse Vibrations of Rectangular Unsymmetrically Laminated Plates," J. Sound Vib., <u>36</u> (1), pp 91-103 (1974).
- 161. Mau, S.-T. and Pian, T.H.H., "Linear Dynamic Analyses of Laminated Plates and Shells by the Hybrid-Stress Finite-Element Method," Mass. Inst. Tech., Aeroelastic Struc. Res. Lab., Rept. No. ASRL-TR-172-2 (1973).
- 162. Mau, S.-T., Pian, T.H.H., and Tong, P., "Vibra-

- tion Analysis of Laminated Plates and Shells by a Hybrid Stress Element," AIAA J., 11 (10), pp 1450-1452 (1973).
- 163. McCullers, L.A. and Naberhaus, J.D., "Automated Structural Design and Analysis of Advanced Composite Wing Models," Computers and Struc., 3 (4), pp 925-935 (1973).
- 164. Minich, M.D. and Chamis, C.C., "Analytical Displacements and Vibrations of Cantilevered Unsymmetric Fiber Composite Laminates," NASA, Lewis Res. Ctr., Rept. No. NASA-TM-X-71699 (1975).
- 165. Minnich, M.D. and Chamis, C.C., "Cantilevered Unsymmetric Fiber Composite Plates," AIAA J., 14 (3), pp 299-300 (1976).
- 166. Mirza, S. and Singh, A.V., "Axisymmetric Vibration of Circular Sandwich Plates," AIAA J., 12 (1), pp 1418-1420 (1974).
- Nelson, R.B. and Dong, S.B., "High Frequency Vibrations and Waves in Laminated Orthotropic Plates," J. Sound Vib., 30 (1), pp 33-44 (1973).
- Noor, A.K., "Mixed Finite Difference Scheme for Analysis of Simply-Supported Thick Plates," Computers and Struc., 3, pp 967-982 (1973).
- Noor, A.K., "Free Vibrations of Multilayered Composite Plates," AIAA J., 11 (7), pp 1038-1039 (1973).
- 170. Rao, Y.V.K.S. and Nakra, B.C., "Theory of Vibratory Bending of Unsymmetrical Sandwich Plates," Arch. Mech. Stosowanej, <u>25</u> (2), pp 213-225 (1973).
- 171. Sierakowski, R.L. and Sun, C.T., "Experimental Investigation of the Dynamic Response of Cantilever Anisotropic Plates," Shock Vib. Bull., U.S. Naval Res. Lab., Proc., No. 44, Pt. 5, pp 89-98 (1974).
- Solecki, R., "Oscillations of Rectangular Sandwich Plates with Concentrated Masses,"
 J. Sound Vib., 33 (3), pp 295-303 (1974).

- 173. Sun, C.-T. and Whitney, J.M., "Forced Vibrations of Laminated Composite Plates in Cylindrical Bending," J. Acoust. Soc. Amer., 55 (5), pp 1003-1008 (1974).
- 174. Steinberg, D.S., "Avoiding Vibration in Odd-Shaped Printed Circuit Boards," Des., 48 (12), pp 116-119 (1976).
- 175. Thomas, C.R., "Flexural and Extensional Vibrations of Simply Supported Laminated Rectangular Plates," J. Acoust. Soc. Amer., 57 (3), pp 655-659 (1975).

ANNUAL ARTICLE INDEX

FEATURE ARTICLES

	ISSUE	PAGES
Murphy, G. Scaling and Modeling for Experiment	1	5-13
Lyon, R.H. Recent Developments in Statistical Energy Analysis	2	3-7
Hales, F.D. Ride Handling Dynamics of Road Vehicles (A Review of Recent Literature)	3	3-8
Dubey, R.N. Vibration of Overhead Transmission Lines	4	3-6
Bernard, J.E. Computer Programs for the Directional Response of Highway Vehicles	5	3-8
Drenick, R.F. and Wang, P.C. System Reliability Assessments Using Critical Excitations	6	3-7
Attenborough, K. Sound Attenuation Over Ground Cover	7	3-13
Beards, C.F. Damping Overhead Transmission Line Vibration	8	3-8
Stadelbauer, D.G. Balancing Machines Reviewed	9	3-9
Romilly, N. Guided Sound Transmission Through Layers	10	3-7
Jlsoy, A.G. and Mote, C.D., Jr. Band Saw Vibration and Stability	11	3-15
Seshadri, T.V. Shock and Vibration Analysis Using Finite Element Techniques	12	3-9

LITERATURE REVIEWS

	ISSUE	PAGES
Ibrahim, R.A. and Barr, A.D.S. Parametric Vibration. Part I. Mechanics of Linear Problems	1	15-29
Dix, R.C. Dynamic Analysis for Rigid-Link Mechanisms	1	31-33
Ibrahim, R.A. and Barr, A.D.S. Parametric Vibration. Part II: Mechanics of Nonlinear Problems	2	9-24
Scott, R.A. Linear Elastic Wave Propagation. An Annotated Bibliography: Part I	2	25-41
Scott, R.A. Linear Elastic Wave Propagation. An Annotated Bibliography: Part II	3	11-39
Ibrahim, R.A. Parametric Vibration. Part III: Current Problems (1)	3	41-57
Massoud, M. and Pastorel, H. Impedance Methods for Machine Analysis	4	9-18
Ibrahim, R.A. Parametric Vibration. Part IV: Current Problems (2)	4	19-47
De, S. On Seismic Waves. Part I: Introduction	. 5	11-16
Ibrahim, R.A. and Roberts, J.W. Parametric Vibration. Part V: Stochastic Problems	5	17-38
De, S. On Seismic Waves. Part II: Surface Waves and Guided Waves	6	9-14
Mote, C.D., Jr. and Szymani, R. Circular Saw Vibration Research	6	15-30
DiMaggio, F.L. Recent Research on the Dynamic Response of Fluid-Filled Shells	. 7	15-19
De, S. On Seismic Waves. Part III: Mathematical Methods	7	21-43
De, S. On Seismic Waves. Part IV: Mathematical Methods (2)	8	11-26
Venancio Filho, F. Finite Element Analysis of Structures Under Moving Loads	8	27-35

LITERATURE REVIEWS (CONTINUED)

	ISSUE	PAGES
Platzer, M.F. Transonic Blade Flutter: A Survey of New Developments	9	11-20
Jones, N. Recent Progress in the Dynamic Plastic Behavior of Structures. Part I	9	21-33
Nielsen, L.E. Mechanical Damping of Filled Plastics	10	9-11
Jones, N. Recent Progress in the Dynamic Plastic Behavior of Structures. Part II	10	13-19
Chung, T.J. Thermomechanical Vibrations	11	17-25
Ramamurti, V., Sathikh, S., and Chari, R.T. Transmission Line Vibrations	11	27-31
Arndt, R.E.A. A Sketch of Aeroacoustics	12	11-19
Leissa, A.W. Recent Research in Plate Vibrations. 1973-1976: Complicating Effects	12	21-35

BOOK REVIEWS

COMPUTING IN APPLIED MECHANICS

R.F. Hartung, Editor
The American Society of Mechanical Engineers
New York, 1976

This book is a collection of nine papers that were presented at the ASME Winter Annual Meeting in New York in December 1976. The papers comprised a symposium organized by the Applied Mechanics Division's Committee on Computing to highlight various aspects of computerized analysis in applied mechanics.

Schaeffer's paper has to to with the advances in computer hardware, numerical analysis, and computer science and discusses his perception of future finite element analysis codes using NASTRAN as a base line. He identifies developments required in supporting technological areas and discusses the concept of a National Software Center to disseminate valuable software resources.

Smith and Craig consider the role of the minicomputer in experimental mechanics. They describe appropriate hardware and software and provide examples of effective systems.

Vanderplaats considers the role of the computer in design synthesis. He describes numerical optimization techniques and discusses methods of coupling these techniques with analysis procedures to achieve fully automated design capability.

MacCormic's paper is concerned with the field of computational fluid mechanics. He presents a new numerical technique for solving such systems of equations as the time-dependent Navier-Stokes equations at high Reynolds numbers.

Gartling reviews recent developments in the use of the finite element to solve problems of viscous incompressible flow. He also discusses the coupled fluid/thermal problem and presents problem formulations, solution methods, and example problems.

The paper by Egan et al discusses interesting applications of the computer to environmental studies. Two broad categories are defined: computer simulation in the analysis of air pollution and data acquisition and storage for environmental studies.

Tong describes computational methods used to analyze dynamic problems associated with ground transportation. The four specific problem areas discussed are vehicle crashworthiness prediction, rail vehicle dynamics, and train handling and track wear

Belytschko considers methods for computer analysis of wave propagation and shock. The methods are categorized as methods of characteristics, semi-discretization methods, and hybrid methods.

Finally Bathe surveys the computational methods for analysis of problems in structural dynamics. He presents the numerical formulation and discusses methods appropriate for linear and nonlinear analyses.

The book contains a brief summary of each paper by Hartung; the sympsoium organizer; he draws the following general conclusions.

- The computer, coupled with computer-oriented computational schemes, has been instrumental in achieving the level of sophistication that exists in many areas of applied mechanics.
- Further advances in computational applied mechanics will depend more upon advances in computer technology and numerical analysis than upon breakthroughs in applied mechanics.
- Computational methods are a common ingredient in work being done in most areas of applied mechanics. At the computational level many of the different areas begin to look similar.

The computer may well serve the purpose of promoting more interdisciplinary work within applied mechanics.

- The use of the computer in design (as opposed to analysis) remains limited, primarily because of high computer costs. As more powerful computing hardware becomes available, the computer will become an important design tool in applied mechanics.
- Dynamic problems are common to many areas of applied mechanics, and their solution is presently receiving much attention. New numerical integration methods that are being developed will lead to more solutions per computer dollar.
- A vast national resource exists in the many computer programs that have been developed in applied mechanics and other fields of technology. No one has yet found a satisfactory solution for disseminating, maintaining, and providing technical support for these programs.
- The use of computers for data acquisition, data reduction, and control of experiments has become more common with the advent of low cost, high power minicomputers.

Harry G. Schaeffer Schaeffer Analysis Kendall Hill Road Mont Vernon, NY 03057

THE COMPONENT ELEMENT METHOD IN DYNAMICS

S. Levy and J.P.D. Wilkinson
McGraw-Hill Book Company, New York, NY

Many dynamics books are published, but this is one of the more outstanding ones because it contains topics concerned with current design problems. Subjects usually found only in specialized volumes are included: finite elements, structurally-induced vibrations, vehicle dynamics, turbine bucket analysis under centrifugal loads, and earthquake design. The nine chapters progress from elementary to more advanced vibration topics.

Chapter I is concerned with force, mass, damping, and stiffness; forced response is included, as is a good discussion of the Newmark, Houbolt, and Wilson

methods applied to the dynamic response of linear and nonlinear systems.

Chapter II has to do with the dynamics of singlemass systems and nonlinearities of springs and dampers. A fully detailed computer program used by the authors in the past few years is included.

Chapter III describes multi-degree-of-freedom systems in matrix notation and applies the information to beam dynamics and forced responses of linear and nonlinear systems. The stiffness matrix of a beam with shear deformation is considered, and an extensive computer program developed by the authors is given.

Chapter IV begins with basic linear and nonlinear problems and goes on to applied engineering problems; i.e., vehicle dynamics, aircraft landings, locomotive dynamics, car (train) dynamics, and aircushion vehicle dynamics. This information is not available in any other book.

In the reviewer's opinion Chapter V on finite elements is excellent. Few dynamics books even discuss finite elements. The simple spring is described first, then two-dimensional elastic continuum and isoparametric elements. Three-dimensional solid elements are described for the first time in a book on dynamics.

Chapter VI, a continuation of the previous chapter, includes information on the direct use of Eigenvalue solutions via Jacobi's method, the Eigenvalue economizer method, and more modern iterative approaches. The reviewer commends the authors for their inclusion of the dynamics of a turbine blade subjected to centrifugal forces -- another first in a dynamics book and also a practical engineering problem in stiffness matrix form.

Chapter VII applied the methods from Chapter VI to the direct response of composite aircraft fan blades and includes a description of impact loading.

Chapter VIII considers the study of seismic response of power plants with finite elements. Design response spectra, generation of artificial design response spectra, substructuring, and soil-structure interaction are included. There is a good section on component mode synthesis.

The final chapter discusses vibration of structural components submerged in water. The subject is directly applicable to reactor internals, marine design, and heat exchanger design. The study of fluid dynamics using finite elements is briefly discussed.

In summary, the book is well written and contains much information not found in many dynamics books. The reviewer would have liked a section on random vibrations and a section on variational methods. The transfer matrix method is not discussed even though many engineers use this version of dynamic analysis. Nevertheless, the book is recommended to persons involved in dynamics.

Herb Saunders General Electric Company Building 41, Room 319 Schenectady, NY 12345

BOOK REVIEWS: 1978

Bartlett, J.H., Classical and Modern Mechanics, The University of Alabama Press, University, AL; 1975, Reviewed by M. Taylor, SVD, 10 (10), p 21 (Oct 1978)

Bathe, K.-J. and Wilson, E.L., Numerical Methods in Finite Element Analysis, Prentice-Hall, Inc., Englewood Cliffs, NJ; Reviewed by H. Saunders, SVD, 10 (9), pp 34-35 (Sept 1978)

Blevins, R.D., Flow-Induced Vibration, Van Nostrand-Reinhold; 1977, Reviewed by R.H. Scanlon, SVD, 10 (6), p 33 (June 1978)

Bolotin, V.V., <u>Application of Methods of Theory of Probability and Theory of Reliability to Analysis of Structures</u>, AD 776115, Reviewed by H. Saunders, SVD, <u>10</u> (11), pp 32-33 (Nov 1978)

Bolt, B.A., <u>Nuclear Explosions and Earthquakes</u>, <u>The Parted Veil</u>, W.H. Freeman and Company, San Francisco; 1976, Reviewed by H.C. Pusey, SVD, 10 (8), p 36 (Aug 1978)

Byrne, R., ed., <u>Symposium on Railroad Equipment Dynamics</u>, The American Society of Mechanical Engineers, New York, NY; 1976, Reviewed by A.B. Perlman, SVD, 10 (9), p 36 (Sept 1978)

Campbell, J.D., <u>Dynamic Plasticity of Metals</u>, Springer-Verlag; 1972, Reviewed by J. Lipkin, SVD, <u>10</u> (3), p 58 (Mar 1978)

Chen, P., Thermodynamic Effects in Wave Propagation; Reviewed by T.C.T. Ting, SVD, 10 (11), p 32 (Nov 1978)

Cheremisinoff, P.N. and Cheremisinoff, P., <u>Industrial Noise Control Handbook</u>, Ann Arbor Science, Ann Arbor, MI; 1977, Reviewed by R.J. Peppin, SVD, 10 (7), pp 46-47 (July 1978)

Eringen, A.C. and Suhubi, E.S., Elastodynamics, Volume 1. Finite Motions, Academic Press, New York and London; 1974, Reviewed by K.S. Pister, SVD, 10 (9), p 35 (Sept 1978)

Evan-Iwanowski, R.M., Resonance Oscillations in Mechanical Systems, Elsevier Scientific Pub., The Netherlands; 1976, Reviewed by C.L. Dym, SVD, 10 (7), p 46 (July 1978)

Harris, C.M. and Crede, C.E., eds., Shock and Vibration Handbook, (2nd Edition), McGraw-Hill Book Company, New York; 1976, Reviewed by H. Saunders, SVD, 10 (1), p 34 (Jan 1978)

Harris, C.M. and Crede, C.E., eds., Shock and Vibration Handbook, (2nd Edition), McGraw-Hill Book Company, New York; 1976, Reviewed by R.H. Volin, SVD, 10 (1), pp 35-36 (Jan 1978)

Hartung, R.F., ed., Computing in Applied Mechanics, The American Society of Mechanical Engineers, New York; 1976, Reviewed by H.G. Schaeffer, SVD, 10 (12), pp 39-40 (Dec 1978)

Hartung, R.F., ed., Integrated Design and Analysis of Aerospace Structures, The American Society of Mechanical Engineers, New York; 1975, Reviewed by R.L. Dreisbach, SVD, 10 (2), pp 44-45 (Feb 1978)

Hult, J., ed., Mechanics of Visco-Elastic Media and Bodies, Springer-Verlag; 1975, Reviewed by P.J. Chen, SVD, 10 (7), pp 45-46 (July 1978)

Kalnins, A. and Dym, C.L., eds., Vibration: Beams, Plates and Shells, Halsted Press; 1976, Reviewed by J.E. Goldberg, SVD, 10 (10), pp 21-22 (Oct 1978)

Levy, S. and Wilkinson, J.P.D., <u>The Component Element Method in Dynamics</u>, McGraw-Hill Book Co., New York; Reviewed by H. Saunders, SVD, 10 (12), pp 40-41 (Dec 1978)

Lomakin, V.A., <u>Statistical Problems in Mechanics of Solid, Deformable Bodies (Statisticheskie zadachi mekhaniki tverdykh deformiruemykh tel)</u>, Moscow, Izdatelstvo Nauka; 1970, Reviewed by Z. Sobotka, SVD, <u>10</u> (1), p 36 (Jan 1978)

Lumb, P., ed., Statistics and Probability in Civil Engineering, Hong Kong, University Press; 1972, Reviewed by S.M. Holzer, SVD, 10 (4), p 48 (Apr 1978)

Mallett, R.H., ed., <u>Limit Analysis Using Finite Elements</u>, Symp. Proc.; Reviewed by P.G. Hodge, Jr., SVD, <u>10</u> (7), pp 44-45 (July 1978)

Medearis, K.G., Structural Response to Explosion-Induced Ground Motions, ASCE, New York; 1975, Reviewed by V.H. Neubert, SVD, 10 (4), p 49 (Apr 1978)

Miller, R.K., Handbook of Industrial Noise Management, The Fairmont Press, Inc.; 1976, Reviewed by G. Schweitzer, SVD, 10 (2), p 43 (Feb 1978)

Naudascher, E., ed., Flow-Induced Structural Vibration, Springer-Verlag, Berlin, Heidelberg, New York; Reviewed by H. Saunders, SVD, 10 (10), pp 20-21 (Oct 1978)

Nowacki, W., <u>Dynamic Problems of Thermoelasticity</u>, Noordhoff International Publishing, Leyden, The Netherlands; 1975, Reviewed by W.D. Pilkey, SVD, 10 (8), p 38 (Aug 1978)

Price, W.G. and Bishop, R.E.D., <u>Probabilistic Theory of Ship Dynamics</u>, Halsted Press, New York; Reviewed by H. Saunders, SVD, 10 (6), p 32 (June 1978)

Reismann, H. and Pawlik, P.S., <u>Elastokinetics</u>, West Publishing Company, St. Paul, Minnesota; Reviewed by H. Saunders, SVD, 10 (5), pp 40-41 (May 1978)

Rikards, R.B. and Teters, G.A., Stability of Shells Made of Composite Materials (Ustoichivost obolchek iz kompozitnykh materialov), Riga, Izdatelstvo "Zinatne"; 1974, Reviewed by W.A. Nash, SVD, 10 (2), p 42 (Feb 1978)

Saczalski, K., Measurement and Prediction of Structural and Biodynamic Crash-Impact Response, American Society of Mechanical Engineers, New York; 1976, Reviewed by H. Armen, Jr., SVD, 10 (8), pp 36-37 (Aug 1978)

Syndararajan, C., <u>Dynamic Analysis of Pressure Vessel and Piping Components</u>, American Society of Mechanical Engineers, New York; 1977, Reviewed by P.S. Chopra, SVD, 10 (11), p 33 (Nov 1978)

Thoma, J.U., <u>Introduction to Bond Graphs and Their Applications</u>, Pergamon Press; 1975, Reviewed by D. Karnopp, SVD, 10 (3), p 59 (Mar 1978)

Wasley, R.J., Stress Wave Propagation in Solids. An Introduction, Marcel Dekker, Inc., New York; 1973, Reviewed by W. Herrman, SVD, 10 (5), pp 39-40 (May 1978)

Development of the Mechanics of Gyroscopic and Inertial Systems (Razvitie mekhaniki giroskopicheskikhi inertsialnykh sistem), Moscow, Izdatelstvo "Nauka"; 1973, Reviewed by V. Chobotov, SVC, 10 (2), pp 42-43 (Feb 1978)

Developments in Mechanics, Volume 8, Proceedings fo the 14th Midwestern Mechanics Conf.; Reviewed by L.Y. Bahar, SVD, 10 (8), pp 37-38 (Aug 1978)

SHORT COURSES

DECEMBER

MACHINE PROTECTION AND MALFUNCTION DIAGNOSIS

Dates:

December 11-15, 1978

Place:

Carson City, Nevada

Objective: Topics to be covered include: Measuring and monitoring parameters for predictive maintenance; Eddy current probe and proximitor theory of operation; Installation procedures and common pitfalls; Permanent machine monitoring systems; System calibration procedures; Thrust position measurements; Troubleshooting the system; Transducer polarity rules; Hazardous area considerations; Introduction to machine data acquisition; Oscilloscope theory and operation; Oscilloscope cameras; Tunable filters, Vector filter-phase meter; Tape recorders; Keyphasor theory; and Electrical runout.

Contact: Training Manager, Bently Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611

1979

JANUARY

NONDESTRUCTIVE EXAMINATION

Dates:

Repeated continuously through-out the

year (1 day to 3 weeks)

Place:

Los Angeles, CA

Objective: For those requiring qualification and certification, theory and practical application courses are available for either one or all of the basic techniques; Ultrasonics, Radiographic, Magnetic Particle, Liquid Penetrant, Eddy Current and Helium Leak. Also Special Radiation Safety and Radiographic Film Interpretation courses for Level II and Level III training are presented. The selection of courses is also applicable to those who require engineering understanding, supervision training or state-of-the-art development.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates:

s: January 8-12, 1979

Place: The Ge

The George Washington University

Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structures programming and software engineering, including stepwise refinement, program correctness, and top-down system development.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

ENVIRONMENTAL ACOUSTICS

Dates:

January 10 to March 21, 1979

(Wednesdays, 7-10 p.m.)

Place: UCLA Extension, Los Angeles, CA Objective: This course will cover acoustic measurements, noise metrics and human criteria, sound propagation and attenuation, vehicle and aircraft noise, sound in rooms, acoustic properties of materials, transmission loss, ducts and mufflers, sound transmission in buildings, vibration control and impact isolation, sound reinforcement, noise law and environmental impact.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

SHOCK AND VIBRATION ENGINEERING FOR AEROSPACE SYSTEMS

Dates:

January 9 to March 20, 1979

(Tuesdays, 7-10 p.m.)

Place: UCLA Extension, Los Angeles, CA Objective: This course will cover each facet of shock and vibration engineering in aerospace systems.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

FEBRUARY

VIBRATION AND LOOSE PARTS MONITORING SYSTEMS AND TECHNOLOGY

Dates:

February 5-8, 1979

Place: Los Angeles, California

Objective: A course designed for users, utility designers specifying systems, installers, operators, and analysts of Vibration and Loose Parts Monitoring Systems. Classroom instruction in theory, installation, calibration, alarms and location, signature analysis, noise analysis, and troubleshooting and servicing. Practical demonstration includes student "hands-on" operation of equipment.

C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

FLOW-INDUCED VIBRATION PROBLEMS AND THEIR SOLUTIONS IN PRACTICAL APPLICA-TIONS: TURBOMACHINERY, HEAT **EXCHANGERS AND NUCLEAR REACTORS**

Dates: February 12-16, 1979

Place: The University of Tennessee Space Inst. Objective: The aim of the course is to provide practicing engineers engaged in design, research and service, an in-depth background and exposure to various problems and solution techniques developed in recent years. Topics to be covered will be the fundamental principles of unsteady fluid flow, structural vibration and their interplay; review of the morphology of flow-induced vibration; stateof-the-art discussion upon theory, experimental techniques and their interaction; methodology of alleviation.

Contact: Jules Bernard, The University of Tennessee Space Institute, Tullahoma, TN 37388 - (615) 455-0631 - Ext. 276 or 277.

MACHINERY VIBRATIONS COURSE

Dates: February 26-March 1, 1979

Shamrock Hilton Hotel, Houston, Texas Place: Objective: This course on machinery vibrations will cover physical/mathematical descriptions, calculations, modeling, measuring, and analysis. Machinery vibrations control techniques, balancing, isolation, and damping, will be discussed. Techniques for machine fault diagnosis and correction will be reviewed along with examples and case histories. Torsional vibration measurement and calculation will be covered.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514 - (312) 654-2254/654-2053.

MARCH

MACHINERY VIBRATION SEMINAR

March 6-8, 1979 Dates:

Place: New Orleans, Louisiana

Objective: To cover the basic aspects of rotor-bearing system dynamics. The course will provide a fundamental understanding of rotating machinery vibrations; an awareness of available tools and techniques for the analysis and diagnosis of rotor vibration problems; and an appreciation of how these techniques are applied to correct vibration problems. Technical personnel who will benefit most from this course are those concerned with the rotor dynamics evaluation of motors, pumps, turbines, compressors, gearing, shafting, couplings, and similar mechanical equipment. The attendee should possess an engineering degree with some understanding of mechanics of materials and vibration theory. Appropriate job functions include machinery designers; and plant, manufacturing, or service engineers.

Mr. Frank Ralbovsky, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2349.

MEASUREMENT SYSTEMS ENGINEERING

Dates:

March 12-16, 1979

Place:

Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS

Dates:

March 19-23, 1979

Place:

Phoenix, Arizona

Objective: Program emphasis is on how to increase

productivity, cost-effectiveness and data-validity of data acquisition groups in the field and in the laboratory. The program is intended for engineers, scientists, and managers in industrial, governmental, and educational organizations. Electrical measurements of mechanical and thermal quantities are the major topics.

Contact: Peter K. Stein, 5602 E. Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

APPLICATIONS OF THE FINITE ELEMENT METHOD TO PROBLEMS IN ENGINEERING

Dates:

March 12-16, 1979

Place: The University of Tennessee Space Inst. Objective: This course will concentrate on material developed recently and provide a solid foundation for those relatively new to the field. Topics to be covered are the treatment of mixed type equations which occur in transonic flow and wave motion in nonlinear solids, mixed type elements which are of importance in systems such as the Navier-Stokes equations, the interrelationship between the equation formation and the iterative scheme needed to solve any of the nonlinear equations, the advantages of hybrid elements, and the use of interactive graphics as an aid to problem solution.

Jules Bernard, The University of Tennes-Contact: see Space Institute, Tullahoma, TN 37388 - (615) 455-0631, Ext. 276 or 277.

APRIL

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates:

April 16-20, 1979

Place:

UCLA

Objective: This course covers the latest practical techniques of correlation and coherence analysis (ordinary, multiple, partial) for solving acoustics and vibration problems in physical systems. Procedures currently being applied to data collected from single, multiple and distributed input/output systems are explained to: classify data and systems; measure propagation times; identify source contributions; evaluate and monitor system properties, predict output responses and noise conditions; determine nonlinear and nonstationary effects; and conduct dynamics test programs.

P.O. Box 24902, Continuing Education in Engineering and Mathematics, UCLA Extension, Los Angeles, CA 90024 - (213) 825-3344/825-1295.

MAY

STRUCTURED PROGRAMMING AND SOFTWARE **ENGINEERING**

Dates:

May 21-25, 1979

Place:

The George Washington University

Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structures programming and software engineering, including stepwise refinement, program correctness, and topdown system development.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

JUNE

ACOUSTIC EMISSION STRUCTURAL MONITOR-ING TECHNOLOGY

Dates:

June 18-19, 1979

Place

Los Angeles, California

Objective: A theory and practice course covering each of the various facets of acoustic emission structural monitoring technology; basic phenomena, state-of-the-art applications, field testing experience, applicable codes and standards and instrumentation design and calibration. Includes "hands-on" operation of minicomputer and microcomputer acoustic emission systems. This course is designed for potential users of acoustic emission structural monitoring systems.

C.A. Parker, Nuclear Training Center, Contact: Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

NEWS BRIEFS news on current and Future Shock and Vibration activities and events

CALL FOR PAPERS Design and Applications: Advanced Composite Materials

The Mechanical Failure Prevention Group (MFPG) sponsored by the National Bureau of Standards; Office of Naval Research, Department of the Navy; Department of Energy; and NASA Goddard Space Flight Center will hold its 29th Symposium at the National Bureau of Standards, Gaithersburg, Maryland on May 22-24, 1979. Papers are desired in the following areas: Applications in land, marine, and aerospace systems; Analytical techniques; Fabrication techniques; Non-destructive testing; Failure modes; Environmental effects; and Materials. Proceedings in the form of extended abstracts, 2-4 typewritten pages, will be published by the National Bureau of Standards. Closing date for initial abstracts is January 1, 1979 and for extended abstracts, April 30, 1979. Abstracts should be sent to Jesse E. Stern, Code 721, Goddard Space Flight Center, Greenbelt, Maryland 20771 - (301) 982-2657.

VIBRATION OF BEARINGS

The book Vibration of Bearings by K.M. Ragulskis, A.Y. Jurkauskas, V.V. Atstupenas, A.Y. Vitkute. and A.P. Kulvec has been translated into English by NASA (Rept. No NASA-TT-F-17449; TT-75-52090, 517 pp (Dec 1977) [Engl. transl. of "Vibratsiya podshipnikov" Vilnius, Lit. SSR: Mintis Publishers; 1974, 391 pp]). It contains analytical determination of vibrations and friction torque due to rotation taking into account the hydrodynamic action of a lubricating oil film. Determination of the elastic and damping characteristics of bearings and bearing assemblies are some of the problems considered in this book. The methodology and techniques of measuring the dynamic characteristics of bearings are presented. Experimental data and the methodology of statistical analysis are also given. The Russian version of the book was reviewed in the December 1977 issue of the DIGEST.

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

Analogs and Analog Computation **Analytical Methods Dynamic Programming** Impedance Methods **Integral Transforms** Nonlinear Analysis **Numerical Analysis Optimization Techniques** Perturbation Methods Stability Analysis Statistical Methods Variational Methods Finite Element Modeling Modeling **Digital Simulation** Parameter Identification **Design Information Design Techniques** Criteria, Standards, and **Specifications** Surveys and Bibliographies **Tutorial** Modal Analysis and Synthesis

· COMPUTER PROGRAMS

General Natural Frequency Random Response Stability Steady State Response Transient Response

ENVIRONMENTS

Acoustic Periodic Random Seismic Shock General Weapon Transportation

PHENOMENOLOGY

Composite Damping Elastic Fatigue Fluid Inelastic Soil

Thermoelastic Viscoelastic

EXPERIMENTATION

Balancing

Data Reduction
Diagnostics
Equipment
Experiment Design
Facilities
Instrumentation
Procedures
Scaling and Modeling
Simulators
Specifications
Techniques
Holography

COMPONENTS

Absorbers

Shafts
Beams, Strings, Rods, Bars
Bearings
Blades
Columns
Controls
Cylinders
Ducts
Frames, Arches
Gears
Isolators
Linkages
Mechanical
Membranes, Films, and Webs

Panels
Pipes and Tubes
Plates and Shells
Rings
Springs
Structural
Tires

SYSTEMS

Absorber
Acoustic Isolation
Noise Reduction
Active Isolation
Aircraft
Artillery
Bioengineering
Bridges
Building
Cabinets
Construction
Electrical

Foundations and Earth Helicopters Human Isolation

Material Handling Mechanical

Metal Working and Forming

Off-Road Vehicles

Optical
Package
Pressure Vessels
Pumps, Turbines, Fans,
Compressors

Rail Reactors

Road

Reciprocating Machine

Rotors
Satellite
Self-Excited
Ship
Spacecraft
Structural
Transmissions
Turbomachinery
Useful Application

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI, U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN 51	PHENOMENOLOGY62	Pipes and Tubes
Analytical Methods 51	Damping 62	Structural
Nonlinear Analysis 51	Fatigue 64	Tires
Numerical Analysis 51	Fluid	
Optimization Techniques 52	Soil	SYSTEMS
Statistical Methods 52	Viscoelastic 66	
Finite Element Modeling 52		Absorber
Modeling 53	EXPERIMENTATION 66	Noise Reduction 82
Parameter Identification 53		Aircraft
Design Techniques 54	Balancing66	Building
Criteria, Standards, and	Diagnostics 66	Construction
Specifications 54	Equipment67	Foundations and Earth87
Surveys and	Instrumentation 67	Human
Bibliographies55	Techniques 67	Isolation
Modal Analysis and	·	Mechanical88
Synthesis 56	COMPONENTS 67	Metal Working and
		Forming
COMPUTER PROGRAMS56	Absorbers 67	Off-Road Vehicles
	Shafts	Pumps, Turbines, Fans,
General	Beams, Strings, Rods, Bars . 68	Compressors89
	Bearings	Rail
ENVIRONMENTS58	Blades	Reactors
	Controls	Reciprocating Machine 91
Acoustic	Cylinders	Road91
Random 60	Ducts	Rotors
Seismic 60	Frames, Arches	Self-Excited
Shock 62	Gears	Spacecraft
General Weapon 62	Linkages	Transmissions 94
Transportation 62	Mechanical	Turbomachinery 94

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 1820)

78-1700

Eigenvalue Bounds for Damped Linear Systems D.W. Nicholson

Goodyear Research, The Goodyear Tire and Rubber Co., Akron, OH, Mech. Res. Comm., <u>5</u> (3), pp 147-152 (1978) 4 refs

Key Words: Free vibration, Boundary value problems, Linear systems, Damped structures

Lower bounds are obtained on the real and imaginary parts of the eigenvalues of a damped linear system in free vibration. A condition for subcritical damping in all modes is obtained. The bounds have a close relation to the eigenvalue of a one degree-of-freedom system.

78-1701

Methods for Oscillating Problems

L. Petzold and G.W. Gear

Dept. of Computer Science, Illinois Inst. of Tech., Chicago, IL, Rept. No. C00-2383-45; UILU-ENG-77-1752, 36 pp (Oct 1977) N78-23826

Key Words: Boundary value problems

Initial-value problems for ordinary differential equations with highly oscillatory solutions are considered. A solution method, applicable to linear or nonlinear oscillations, is discussed.

NONLINEAR ANALYSIS

78-1702

A Boundary Tracking Optimization Algorithm for Constrained Nonlinear Problems

J.Y. Morado and M. Pappas

Dept. of Mech. Engrg., Newark College of Engrg. of

the New Jersey Inst. of Technology, Newark, NJ, J. Mech. Des., Trans. ASME, 100 (2), pp 292-296 (Apr 1978) 1 fig, 4 tables, 13 refs

Key Words: Nonlinear programming, Optimization

A new procedure for numerical optimization of constrained nonlinear problems is described. The method makes use of an efficient "boundary tracking" strategy to move on the constraint surfaces. In a comparison study it was found to be an effective method for treating nonlinear mathematical programming problems particularly those with difficult nonlinear constraints.

NUMERICAL ANALYSIS

78-1703

Numerical Solutions of the Unsteady Transonic Small-Disturbance Equations

M.M. Hafez, M.H. Rizk, E.M. Murman, and L.C. Wellford

Flow Research Co., Kent, WA, Rept. No. FLOW-RR-83, AFFDL-TR-77-100, 68 pp (Oct 1977) AD-A054 036/9GA

Key Words: Numerical analysis, Fluid mechanics, Perturbation theory, Harmonic waves, Finite element technique

Three problems pertinent to the numerical solution of the unsteady transonic small-disturbance equation are studied. The first problem is the numerical instabilities arising in the solution of the harmonic perturbation potential equation. Several remedies that have been tested are suggested. The second problem is the movement of unsteady shock waves in the harmonic perturbation approach. A formulation and computed example are presented. The third problem is a finite-element formulation for unsteady transonic flow. Preliminary calculations are given.

78-1704

Dynamic Analysis of Structures Containing Nonlinear Springs

L.D. Hofmeister ·

Systems Dev. Corp., 2500 Colorado Blvd., Santa Monica, CA 90406, Computers Struc., <u>8</u> (5), pp 609-614 (May 1978) 1 fig, 5 tables, 11 refs

Key Words: Linear systems, Nonlinear springs, Iteration

An efficient algorithm is presented for the solution of the dynamics problem of a linear structure containing springs

with nonlinear force-deflection characteristics. The method is based upon the Newmark direct integrator, and uses an iterative procedure in each time step to account for the nonlinear spring behavior. Convergence criteria are derived for the iteration.

OPTIMIZATION TECHNIQUES

(Also see Nos. 1789, 1804, 1821)

78-1705

Sensitivity Analysis and Optimization of Structures for Dynamic Response

E.J. Haug, J.S. Arora, and T.T. Feng Materials Div., College of Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 100 (2), pp 311-318 (Apr 1978) 6 figs, 5 tables, 12 refs

Key Words: Optimum design, Earthquake resistant structures, Blast resistant structures

A state space method of optimal design of structures under transient dynamic excitation is developed and three problems are solved. It is shown that exploitation of the mathematical form of the equations of structural dynamics leads to significant computational efficiencies. A factor of five reduction in computing time is shown to be achievable, relative to more conventional nonlinear programming methods.

STATISTICAL METHODS

(Also see No. 1819)

78-1706

Statistics of Normal Mode Amplitudes in a Random Ocean. II. Computations

L.B. Dozier and F.D. Tappert Courant Inst., New York Univ., New York, NY 10012, J. Acoust. Soc. Amer., 64 (2), pp 533-547 (Aug 1978) 8 figs, 1 table, 19 refs

Key Words: Elastic waves, Normal modes, Statistical analysis, Monte Carlo method

Numerical acoustic propagation theory in a canonical model of a random ocean is evaluated and compared to the results of a large-scale Monte Carlo computer simulation. At each of the acoustic frequencies 50, 100, 200, 500, and 1000 Hz, 100 independent realizations of the random acoustic model are obtained.

FINITE ELEMENT MODELING

(Also see No. 1721)

78-1707

Linear Constraint Equations for Continuous Support Conditions in Finite Element Analysis

D.D. Pfaffinger

Fides Trust Co., Zurich, Switzerland, Computers Struc., $\underline{8}$ (5), pp 553-562 (May 1978) 11 figs, 3 tables, $\underline{12}$ refs

Key Words: Plates, Elastic foundations, Finite element technique

Discretized structural models such as by finite elements imply discretized support conditions. In some cases such as plates on elastic foundation or slabs on large interacting columns an improved formulation of the continuous support conditions is desirable. This can be achieved by means of linear constraint equations. The numerical treatment of linear constraints is discussed for the method of elimination of variables as well as for the method of Lagrange multipliers. Then specific constraint equations for different accuracy requirements are derived, which can be used to constrain rectangular flat shell elements of arbitrary shape functions. The effect on the strain energy of a square shell element is shown for the different constraint equations. As an application, the linear constraints are used to represent the continuous interaction of columns with the plate in a flat slab structure. Comparison of the finite element solutions with analytical results shows that the derived constraint equations allow a considerably improved formulation of continuous support conditions.

78-1708

Finite-Element Analysis of Coupled Thermoviscoelastic Structures Undergoing Sustained Periodic Vibrations

T.L. Cost and J.M. Heard Univ. of Alabama, Tuscaloosa, AZ, AIAA J., <u>16</u> (8), pp 795-799 (Aug 1978) 5 figs, 10 refs

Key Words: Forced vibration, Periodic response, Finite element technique, Thermoviscoelasticity theory, Computer programs

A general method is presented for analyzing the effects of internal heating in geometrically complex viscoelastic structures due to exposure to sustained periodic vibratory loads. The analysis employs the finite-element method for both transient displacement and temperature determinations and utilizes "complex" viscoelastic material property functions. The method is demonstrated by application to a problem involving longitudinal oscillations of a linear visco-

elastic rod. General agreement is obtained with the results of Huang and Lee which appear in the literature. The method is applicable to geometrically complex, linear viscoelastic structures of the thermorheologically simple type undergoing small deformations. Existing computer codes that model linear elastic materials can be used, with minor modifications, to obtain linear viscoelastic results.

MODELING

78-1709

Dynamic System Simplification: A Time Domain Criterion

R.G. Leonard and E.D. Ward

Automatic Control Center, School of Mech. Engrg., Purdue Univ., West Lafayette, IN 47907, J. Sound Vib., 59 (1), pp 15-21 (July 8, 1978) 6 figs, 1 table, 2 refs

Key Words: Mathematical models, Dynamic systems

This paper explores the conditions under which second and third order dynamic systems can be reduced to systems of lower order. The performance criterion chosen is the 2% settling time in response to a step input to the system. Graphical results are presented which depict the conditions for the valid reduction of second order systems to first order dominant, third order systems to first order dominant, and third order systems to second order dominant.

78-1710

Model Verification of Mixed Dynamic Systems J.D. Chrostowski, D.A. Evensen, and T.K. Hasselman Engrg. Mechanics Dept., J.H. Wiggins Co., Redondo Beach, CA, J. Mech. Des., Trans. ASME, 100 (2), pp 266-273 (Apr 1978) 6 figs, 3 tables, 15 refs

Key Words: Mathematical models, Dynamic systems

A general method is presented for using experimental data to verify math models of "mixed" dynamic systems. The term "mixed" is used to suggest applicability to combined systems which may include interactive mechanical, hydraulic, electrical, and conceivably other types of components. Automatic matrix generating procedures are employed to facilitate the modeling of passive networks (e.g., hydraulic, electrical). These procedures are augmented by direct matrix input which can be used to complement the network model. The problem of model verification is treated in two parts; verification of the basic configuration of the model and determination of the parameter values associated with that configuration are addressed sequentially. Statistical parame-

ter estimation is employed to identify selected parameter values, recognizing varying degrees of uncertainty with regard to both experimental data and analytical results. An example problem, involving a coupled hydraulic-mechanical system, is included to demonstrate application of the method.

78-1711

Stored Response Modeling

J. Eichler

Dept. of Mech. Engrg., Ben-Gurion Univ. of the Negev, Beer-Sheva, Israel, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 132-139 (June 1978) 6 figs, 2 tables, 6 refs

Key Words: Mathematical models, System identification technique, Stored response modeling

A direct "brute force" method of system identification is presented. The method is based on the definition of a deterministic system and applicable to nonlinear nonstationary systems with measurement noise. The approach is to discretize the state of the system (or equivalent measurable state), the input vector and time (in the case of a nonstationary system). An optimal control problem is solved using the SRM model.

PARAMETER IDENTIFICATION

(Also see Nos. 1711, 1868)

78-1712

Instrumental Variables Algorithm for Modal Parameter Identification in Flutter Testing

W. Johnson and N.K. Gupta

Ames Res. Center, NASA, Moffett Field, CA, AIAA J., <u>16</u> (8), pp 800-806 (Aug 1978) 4 figs, 1 table, 12 refs

Key Words: Aircraft, Flutter, Testing techniques, Parameter identification technique

An instrumental variables algorithm for modal parameter identification is derived in the frequency domain, and an example of its use in aeroelasticity testing is given. Basically the algorithm fits a set of poles and zeros to the measured transfer function of a linear, time-invariant system. An instrumental variables estimate is similar to a least-squared-error estimate but without the bias of the latter for noisy data. The algorithm was implemented for on-line data reduction using a minicomputer-based analysis system, with less core and computation time requirements than the data acquisition process. With the instrumental variables algo-

rithm, accurate and reliable stability estimates can be obtained from a reasonable length of data.

DESIGN TECHNIQUES

(See No. 1799)

CRITERIA, STANDARDS, AND SPECIFICATIONS

78-1713

Practice and Principle in Environmental Noise Rating

D.W. Robinson

National Physical Lab., Teddington, UK, Rept. No. NPL-Ac-81, 24 pp (Apr 1977)

N78-23885

Key Words: Noise measurement, Standards

The possibility to derive a comprehensive noise index was studied to abandon established practices. Some classes of noise evaluation and planning problems are soluble only within a unified system. These are outlined, together with brief reviews of progress on standardization in UK, USA, and ISO. The scale of noise measurement on which such progress is possible is the A-weighted equivalent continuous sound level, Leq.

78-1714

The Ramifications of Noise Control in Food Plants

W.W. Carey

Nestle Enterprises, Inc., White Plaines, NY, S/V, Sound Vib., 12 (7), pp 22-24 (July 1978) 2 figs, 1 table, 5 refs

Key Words: Noise control, Standards and codes

Current OSHA requirements for engineering control of worker noise exposure conflict with both FDA and USDA sanitation requirements and GMP's for food manufacturing facilities. A comparison of these conflicting requirements is made and examples provided which indicate both the difficulties and magnitude of costs faced by those who must comply with these standards. Approaches being practiced by many processors are reviewed and future actions pertaining to resolution of the Agency conflict are discussed.

78-1715

Locomotive In-Cab Noise -- Towards a Standardized

Measurement Methodology

R.M. Clarke, R.D. Kilmer, and D.S. Blomquist National Bureau of Standards, Washington, D.C., In: NOISE-CON Conf. on Noise Control Engrg., Langley Res. Center, NASA, Hampton, VA, pp 431-442 (Oct 1977)

Sponsored by the Federal Railroad Administration PB-280 396/3GA

Key Words: Locomotives, Noise measurement, Measurement techniques, Measuring instrumentation, Standards and codes

The U.S. Federal Railroad Administration, in cooperation with the Association of American Railroads, is currently sponsoring efforts by the National Bureau of Standards to collect locomotive in-cab noise level data. The purpose of the program is to develop a simplified stationary test procedure which will correlate with operational duty cycle, crew exposure, and noise level data, and which is based on current OSHA hearing conservation regulations. This paper describes the measurement methodology and instrumentation system developed for this program. The data and conclusions presented are preliminary in nature. The program is scheduled for completion in early 1978.

78-1716

The National Measurement System for Acoustics D.S. Pallett and M.A. Cadoff

National Bureau of Standards, Washington, D.C., Sound and Vibration 11, No. 10, pp 20-25, 27-31 (Oct 1977)

Key Words: Noise measurement, Measurement techniques, Standards and codes

Many recent acoustical measurement processes have been motivated by societal concern over noise and have broad relevance to our contemporary technological society. The emphasis of the study of the National Measurement for Acoustics has been to determine the adequacy of these important physical measurements and to promote improvements within the measurement system. The relevant physical quantities are indicated, and the interactions occurring between participants as well as the roles of acoustical standardization institutions are specified. Finally, the status and trends of the system and the NBS role in adapting to changing technology are discussed.

78-1717

Earthquake Ordinances for the City of Los Angeles, California. A Brief Case Study

K.A. Solomon, D. Okrent, and M. Rubin

Dept. of Chemical, Nuclear and Thermal Engrg., California Univ., Los Angeles, CA., Rept. No. UCLA-ENG-7765, NSF/RA-770485, 62 pp (Oct 1977) PB-280 763/4GA

Key Words: Buildings, Earthquake-resistant structures, Regulations

The objective of this paper is to illustrate some of the difficulties in dealing with decisions involving the building code revisions designed to protect against earthquake hazards. Discussed are: the history of earthquakes in the Los Angeles area; recent proposed earthquake ordinances; public sentiment regarding earthquake ordinances (as depicted in newspaper editorials); and comparisons of earthquakes risk for unimproved and improved pre-1933 structures. An appendix contains a brief UCLA report on the situation, as perceived in April 1976, and a copy of a briefing given to Governor Brown by the U.S. Geological Survey in March 1976.

SURVEYS AND BIBLIOGRAPHIES

78-1718

Structural Mechanics Software. Volume 2. May 1975 - May 1978 (A Bibliography with Abstracts) G.W. Reimherr

National Technical Information Service, Springfield, VA., 219 pp (June 1978) NTIS/PS-78/0551/8GA

Key Words: Bibliographies, Computer programs, NASTRAN (computer program), EPSOLA (computer program), SUPER-SCEPTRE (computer program), SINGER (computer program)

The use of computer programs in structural analysis-design problems are cited. Detailed analyses are included of structural problems — applied and theoretical — including stress analysis, vibration, deformation, etc. The major computer programs cited in this report are NASTRAN, EPSOLA, SUPERSCEPTRE, and SINGER. (This updated bibliography contains 213 abstracts, 63 of which are new entries to the previous edition.)

78-1719

Highway Traffic Noise (A Bibliography with Abstracts)

E. Kenton
National Technical Information Service, Springfield,
VA, 190 pp (June 1978)
NTIS/PS-78/0634/2GA

Key Words: Bibliographies, Traffic noise

The citations relate to many aspects of highway noise and its reduction. Studies include transportation noise models, environmental aspects, noise sources, tire-pavement studies, noise barrier design, noise levels, and research in the field. The bibliography also covers highway planning and Government policies in connection with noise pollution abatement and control strategies. Central city investigations are in general excluded.

78-1720

Stability Tests for One, Two, and Multidimensional Linear Systems

E.I. Jury

Dept. of Electrical Engrg. and Computer Sciences, Electronics Res. Lab., Univ. of California, Berkeley, CA 94720, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 105-109 (June 1978) 39 refs

Key Words: Reviews, Stability, Linear systems

This paper reviews analytical stability tests for one-dimensional linear systems since the early tests of E.J. Routh in his famous Adams Prize essay of 1877. The historical background of Routh's stability test and criterion, as well as Fuller's conjecture on its simplification, will be mentioned. In this historical review, the works of Hermite, Sylvester, Maxwell and others as related to the stability problem are also discussed. This review provides the context for a discussion of recent stability tests obtained for two-dimensional and multidimensional linear systems. These tests are described and their computational complexity is discussed in detail. In addition, the applications of stability testing to the study of two- and multidimensional digital filters, numerical analysis of stiff-differential equations, realization of mixed lumped and distributed parameter systems, and the design of output feedback systems will be briefly mentioned. Comments on future research in this area concludes the paper.

78-1721

Finite Element Analysis of Structures Under Moving Loads

F.V. Filho

Faculty of Civil Engrg., COPPE, Federal University of Rio de Janeiro, Brazil, Shock Vib. Dig., 10 (8), pp 27-35 (Aug 1978) 5 figs, 2 tables, 36 refs

Key Words: Reviews, Finite element technique, Moving loads

This review is concerned with the utilization of the finite

element method to obtain stiffness (or flexibility) properties and the properties of the mass of the structural system and of the mass of the loading due to a moving vehicle. A general equation is formulated and specific cases and their methods of solution are described. Significant contributions are reviewed and related whenever possible to work involving continuous or approximate approaches. Areas of further research are indicated.

78-1722

On Seismic Waves. Part IV: Mathematical Methods (2)

S. De

Old Engrg. Office (Qrs.), Santinketan, Birbhum, West Bengal, India, Shock Vib. Dig., 10 (8), pp 11-26 (Aug 1978) 173 refs

Key Words: Reviews, Seismic waves, Earthquake prediction

This second article on mathematical methods includes a brief discussion about earthquake prediction. Suggestions for future research are given in this final section.

78-1723

Damping Overhead Transmission Line Vibration C.F. Beards

Dept. of Mech. Engrg., Imperial College of Science and Tech., London SW7 2BX, UK, Shock Vib. Dig., 10 (8), pp 3-8 (Aug 1978) 17 refs

Key Words: Reviews, Cables (ropes), Transmission systems, Suspended structures

Aeolian vibration of overhead transmission lines can cause line failure through fatigue of the conductor, clamps, or supports. Controlling the vibration to keep dynamic stresses at acceptable levels is essential. The cause of aeolian vibration is reviewed, and several methods for controlling it are presented.

MODAL ANALYSIS AND SYNTHESIS

(See Nos. 1742, 1844, 1889, 1890)

COMPUTER PROGRAMS

GENERAL

(Also see Nos. 1718, 1739)

78-1724

Computer Program for Vibration Prediction of Fighter Aircraft Equipments

R.W. Sevy and M.N. Haller

Computer programs

Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Rept. No. AFFDL-TR-77-101, 218 pp (Nov 1977) AD-A054 598/8GA

Key Words: Aircraft equipment, Vibration prediction,

This study details in-house efforts that culminate in a computer program for the prediction of vibration inputs to equipments mounted in fighter aircraft. Program inputs specify flight conditions, aircraft structural classes, equipment weight, equipment locational coordinates, and mounting categories in order to characterize vibration inputs of fighter aircraft equipments during flight attitudes ranging from straight and level states to a variety of significant flight maneuvers and phases. Program outputs, digital and graphical, are designed to provide the direct spectral information necessary to assemble sequential vibration histories corresponding to fighter aircraft mission profiles.

78-1725

General Aviation Airplane Structural Crashworthiness User's Manual. Volume II. Input-Output Techniques and Applications

M.A. Gamon, G. Wittlin, and W.L. LaBarge Lockheed-California Co., Burbank, CA, Rept. No. LR-28307-VOL-2, FAA-RD-77-189-VOL-2, 185 pp (Feb 1978) AD-A054 317/3GA

Key Words: Computer programs, Collision research (aircraft)

This document provides a comprehensive description of program KRASH as modified. Included in this Volume of the User's Manual are the following sections: user's guide, math model development; KRASH data requirements; and Typical Model Arrangements.

78-1726

General Aviation Airplane Structural Crashworthiness User's Manual. Volume III. Related Design Information

G. Wittlin

Lockheed-California Co., Burbank, CA., Rept. No. LR-28307-3, FAA/RD-77/189-3, 121 pp (Feb 1978) AD-A054 266/2GA

Key Words: Computer programs, Collision research (aircraft)

General information is presented in this report to assist the general aviation airplane industry designer in developing improved structural crashworthiness designs. This report is initiated for the purpose of providing the General Aviation Manufacturers Association (GAMA) members with the basis for understanding the types of procedures, methods and data that are available with regard to structural crashworthiness. This document contains the following sections: (1) General Aviation Airplane Operational and Structural Characteristics; (2) Crash Environment; (3) Occupant Injury Assessment; (4) Structural Data and Methods; and (5) Structural Crashworthiness Design and Compliance Methods.

78-1727

The Digital Calculation of the Operating Parameters of the Mercedes-Benz Accident Simulator (Die digitale Berechnung der Betriebsparameter des Mercedes-Benz Unfallsimulators)

E. Decker and J. Arnemann

Meisenweg 5, 7257 Ditzingen 5, Automobiltech. Z., 80 (6), pp 293-294 (June 1978) 3 figs

Key Words: Collision research (automotive), Computer programs

This paper describes the development of a mathematical model for the accident simulator used at Daimler-Benz, Sindelfingen. The digital computer program predicts the response of the testing for a given set of parameters and will be explained by a practical example.

78-1728

Revision of Simulation Model of Automobile Collisions Computer Program: Investigation of New Integration Algorithm

M. Chi, E. Neal, and J.R. Tucker Chi Associates, Inc., Arlington, VA., Rept. No. DOT-HS-803 294, 142 pp (May 20, 1977) PB-280 753/5GA

Key Words: Computer programs, Collision research (automotive)

SMAC (Simulated Model of Automobile Collisions) is a computerized program which recreates collision events between two automobiles. Its purpose is to provide a data bank from which information on the causes and consequences of these accidents can be drawn and to aid highway planners and the public in general to avoid unnecessary accidents and mitigate the effects of those which are unavoidable. Based on preliminary investigation of the new pro-

cedure, significant progress has been recorded in reducing computer execution time.

78-1729

Users' Manual for Asymmetric Wheel/Rail Contact Characterization Program

R. Heller and N.K. Cooperrider

Dept. of Mech. Engrg., Arizona State Univ., Tempe, AZ, Rept. No. FRA/ORD-78/05, 103 pp (Dec 1977) PB-279 707/4GA

Key Words: Interaction: rail-wheel, Computer programs

Wheel/rail geometric constraint relationships, such as the effective conicity and gravitational stiffness, strongly influence the lateral dynamics of railway vehicles. The principal curvatures of wheel and rail profiles are important parameters in the determination of creep coefficients used in rail vehicle models. In general, these geometric constraints and profile curvatures are nonlinear functions of the wheelset lateral displacement. This report is a users manual for a computer program written in Fortran IV that uses iterative procedures to determine these nonlinear functions for arbitrary wheel and rail profiles. The program computes the wheel/rail contact positions, geometric constraint functions, and profile curvatures for any given wheel profile, rail profile, rail cant angle, and rail gauge for an asymmetric wheelset on asymmetric rails. Analytical methods used and program input and output are described. Results are in the form of printout, punched cards and drum plotter plots. The users manual includes program listings, sample deck set-ups, and sample run output.

78-1730

The Inclusion of Coulomb Friction in Mechanisms Programs with Particular Reference to DRAM

D.C. Threlfall

Central Electricity Generating Board, Berkeley Nuclear Labs., Berkeley, Gloucestershire, UK, Mech. Mach. Theory, 13 (4), pp 475-483 (1978) 12 figs, 6 refs

Key Words: Computer programs, Mechanisms, Coulomb friction

This paper discusses some properties of friction and critically assesses several possible methods of incorporating these into automatic mechanism programs. The method selected, its compromises and its incorporation into a particular computer program DRAM (Dynamic Response of Articulated Machinery) are described in detail. This method is shown to be a successful compromise between theoretical studies of friction and the avoidance of large computational overheads in their application.

78-1731

THIN - A Computer Program for Analyzing the Axisymmetric Behavior of Thin Spherical Shells

H.E. Williams

Naval Weapons Center, China Lake, CA, Rept. No. NWC-TP-5785, GIDEP-E053-0467 AD-B007 306/4GA

Key Words: Computer programs, Spherical shells

The computer program THIN obtains the solution of the equations of equilibrium governing the small deflections of thin spherical shells using an algorithm called "Dynamic Relaxation." It is assumed that the material properties of the shell are constant and that the shell is closed at the apex. The conditions at the outer edge can be chosen to be either clamped, simply-supported or supported on a transverse rollerskate. This report describes the input/output requirements of the program, the behavior of the "Dynamic Relaxation" algorithm and estimates the accuracy of the program by comparing numerical results obtained using THIN with either exact analytical solutions or analytical solutions where accuracy can be assessed.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1714, 1715, 1716, 1719, 1833, 1845, 1846, 1847, 1849, 1850, 1851, 1852, 1853, 1859, 1870)

78-1732

Classifying Road Vehicles for the Prediction of Road Traffic Noise

P.M. Nelson and R.J. Piner Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL-LR-752, 26 pp (1977) PB-280 864/0GA

Key Words: Traffic noise, Noise prediction, Noise measurement

The accuracy of traffic noise predictions obtained using the TRRL computer model of traffic noise depends to a considerable extent on the degree of simplification adopted in categorizing vehicles according to their sound output and speed in the traffic stream. This report examines and summarizes the available data on the acoustic classification of vehicles in traffic streams for predicting traffic noise. Measurements of speed, noise level and vehicle type have been made in road conditions ranging from fairly congested urban situations with speeds around 20 km/h to free flow on motorways with speeds over 100 km/h. The measurements have been used to construct approximate vehicle noise levels and speed characteristics over the speed range 20-100 km/h for up to 6 vehicle categories, and used as input in the TRRL computer model of traffic noise.

78-1733

Traffic Noise in a High-Rise City

N.W.M. Ko

Dept. of Mech. Engrg., Univ. of Hong Kong, Hong Kong, Appl. Acoust., 11 (3), pp 225-239 (July 1978) 3 figs, 3 tables, 16 refs

Key Words: Traffic noise, Urban noise, Noise measurement

Extensive results of traffic noise measured at 258 roadside sites in the high-rise city of Hong Kong are reported. From the results of this investigation the measurement sites can be very simply classified into three categories: enclosed, semienclosed and open. Distinct differences were found in the sound pressure levels L_{10} , L_{50} and L_{90} and in the standard deviations obtained at the enclosed site and at the semienclosed and open sites.

78-1734

Multiple-Reflection Diffuse-Scattering Model for Noise Propagation in Streets

H.G. Davies

Dept. of Mech. Engrg., Univ. of New Brunswick, Fredericton, New Brunswick, Canada, J. Acoust. Soc. Amer., 64 (2), pp 517-521 (Aug 1978) 4 figs, 5 refs

Key Words: Urban noise, Sound propagation, Acoustic scattering

The sound field generated by an omnidirectional point source in an infinitely long, straight street is considered. The field is assumed to be the sum of a multiply-specularly reflected field and a diffuse field that is fed from scattering at the walls at each reflection of the specular field. It is shown that scattering is important close to the source. The sound level depends on the width of the street and the height of the walls and on the reflection and scattering coefficients of the walls.

78-1735

Noise Transmission Through Plates into an Enclosure W.B. McDonald

Langley Res. Center, NASA, Langley Station, VA.,

Rept. No. NASA-TP-1173; L-11906, 44 pp (May 1978) N78-23877

Key Words: Plates, Sound transmission, Enclosures

An analytical model is presented to predict noise transmission through elastic plates into a hard-walled rectangular cavity at low frequencies, that is, frequencies up through the first few plate and cavity natural frequencies. One or several nonoverlapping and independently vibrating panels are considered. The effects on noise transmission of different external-pressure excitations, plate boundary conditions, fluid parameters, structural parameters, and geometrical parameters were investigated.

78-1736

Measurements with an Intensity Meter of the Acoustic Power of a Small Machine in a Room

F.J. Fahy

Inst. of Sound and Vib. Research, Southampton Univ., Southampton S09 5NH, UK, Rept. No. ISVR-TR-94, 27 pp (Sept 1977) N78-23884

Key Words: Machinery noise, Noise measurement, Measurement techniques

A technique which employs two closely spaced pressure microphones, a special purpose circuit, and a sound level meter to measure acoustic intensity in octave bands, is used to estimate the intensity distribution around a small, 1200 electrical watt, machine situated in a room. The total acoustic power estimated therefrom is compared with that obtained by the conventional direct field method. The technique, which appears to be accurate over the range 250-4000 Hz, produces values of intensity and power which are generally less than the direct field values. The difference tends to increase with frequency. A potential for source location application is indicated.

78-1737

Jet Noise Modelling by Geometric Acoustics. Part 1: Theory and Prediction Outside the Cone of Silence

C.L. Morfey and V.M. Szewczyk
Inst. of Sound and Vib. Resea

Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-91-Pt-1, 174 pp (Sept 1977)

N78-23881

Key Words: Jet noise, Noise prediction, Mathematical models

The generation of noise by the turbulent mixing process downstream of a round jet nozzle is investigated and a geometric acoustics model for jet noise radiation outside the cone of silence is developed. For isothermal jets the turbulence is represented as acoustically equivalent to a volume displacement distribution of quadrupole order. For non-uniform density flows (heated jets) the dominant radiation at low Mach numbers is modeled as acoustically equivalent to a volume displacement distribution of dipole order. A volume displacement monopole distribution is also considered as a possible additional source of noise in heated jets. The effect of mean flow-acoustic interaction is modeled separately from the sources. Source non-compactness and convection effects are included in the source description. A jet noise prediction scheme valid for radiation angles outside the cone of silence is developed from the source master spectra and turbulence parameters inferred from rear arc jet noise measurements, using the geometric acoustics model. Agreement between predictions in the forward arc and measured results is very good.

78-1738

Jet Noise Modelling by Geometric Acoustics. Part 2: Theory and Prediction Inside the Cone of Silence C.L. Morfey and V.M. Szewczyk

Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-92-Pt-2,84 pp (Oct 1977) N78-23882

Key Words: Jet noise, Noise prediction, Mathematical models

A geometric acoustics model of jet mixing noise is extended to describe far-field radiation within the cone of silence. The relevant acoustic-mean flow interactions are modeled by an approximation to the WKB type solution. The original monopole solution is generalized to yield high-frequency solutions for the dipole and quadrupole sources used to model jet mixing noise. The exponential decay factor encountered within the cone of silence is theoretically predicted to be almost proportional (in decibels) to the shear layer thickness. Analysis of a wide range of isothermal jet noise data leads to inferred values of the ratio of shear layer thickness at the source location to the nozzle diameter, as a function of Strouhal number. These are in excellent agreement with the results of source location and flow profile measurements.

78-1739

Jet Noise Modelling by Geometric Acoustics. Part 3: A Computer Program for the Prediction of Jet Mixing Noise

C.L. Morfey and V.M. Szewczyk

Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-93-Pt-3, 29 pp (Oct 1977) N78-23883

Key Words: Jet noise, Noise prediction, Computer programs

A prediction program for far-field jet mixing noise is documented. The theory is based upon Morfey's geometric acoustics model of jet mixing noise. The program is valid for radiation angles greater than 30 deg to the jet axis and for any jet static temperature ratio. Any velocity ratio may be predicted outside the cone of silence, but there is at present an upper limit inside the cone of silence. Sound pressure levels in 1/3 octave bands are predicted for a source Strouhal number range of 0.1 to 3.16, corresponding to a frequency range of 5 octaves centered approximately on the peak 1/3 octave frequency.

78-1740

Noise Suppression in Jet Inlets

B. Zinn, W.L. Meyer, and W.A. Bell School of Aerospace Engrg., Georgia Inst. of Tech., Atlanta, GA., Rept. No. AFOSR-TR-78-0696, 52 pp (Feb 1978) AD-A054 173/0GA

Key Words: Jet noise, Geometric effects, Numerical analysis, Computer programs

This report summarizes the work performed during the first year of a research effort to determine the sound fields associated with jet engine inlet configurations. A solution approach for axisymmetric bodies based upon the integral formulation of the wave equation has been developed. This solution approach circumvents the uniqueness problems which normally occur at certain frequencies when 'straightforward' solutions of the integral equation are obtained. A numerical method and a computer program for solving for the acoustic field associated with general inlet configurations and boundary conditions have also been developed. To evaluate the numerical method, computed and exact results are compared for a sphere and a finite length cylinder. For continuous boundary conditions, the agreement is within ten per cent over a range of nondimensional frequencies from one to ten. For discontinuous boundary conditions, the numerical errors increased by a factor of two. This report presents results for a given inlet configuration and the computed and exact solutions are shown to agree to within ten per cent over the nondimensional frequency range from one to ten.

78-1741

Experimental Measurements of Acoustic Scattering

by Rows of Cylindrical Obstacles

S. Liao and W. Sachse

Dames & Moore, Cranford, NJ 07016, J. Acoust. Soc. Amer., <u>64</u> (2), pp 563-570 (Aug 1978) 11 figs, 14 refs

Key Words: Underwater sound, Acoustic scattering, Cylinders

Experiments were performed in a shallow two-dimensional water tank to determine the effects of diameter, spacing, and material properties on acoustic scattering by rows of cylindrical obstacles. Cylinder diameters ranged from 0.17 to 0.39 times the wavelength, and center-to-center spacings up to 1.2 wavelengths were investigated. In the limit of small spacings, multiple scattering was found to be characteristically similar to sound wave transmission through walls. Analysis of the experimental data indicated that the acoustic properties and microstructure of the scatterers could be distinguished by the transmissivity response of the arrays.

RANDOM

(See Nos. 1781, 1782)

SEISMIC

(Also see Nos. 1705, 1717, 1722, 1799, 1828, 1858, 1876)

78-1742

Simulation of Strong-Motion Displacements Using Surface-Wave Modal Superposition

H.J. Swanger and D.M. Moore
Dept. of Geophysics, Stanford Univ., Stanford, CA
94305, Bull. Seismol. Soc. Amer., <u>68</u> (4), pp 907922 (Aug 1978) 10 figs, 4 tables, 27 refs

Key Words: Ground motion, Simulation, Modal synthesis

Synthetic seismograms constructed by addition of surfacewave modes in a layered half-space are compared to Cagniardde Hoop calculations of Heaton and Helmberger (1977, 1978) and to ground displacement recordings near El Centro, California to examine the applicability of modal superposition as a means of simulating ground motion of possible engineering interest. Ground displacement recordings of El Centro from the 1968 Borrego Mountain earthquake are modeled using a multi-layered geological structure and a source model based on independent studies.

78-1743

New Discrete Models and Their Application to Seismic Response Analysis of Structures

T. Kawai

Inst. of Industrial Science, Univ. of Tokyo, 22-1, Roppongi 7 Chome, Minato-ku, Tokyo 106, Japan, Nucl. Engr. Des., 48 (1), pp 207-229 (June 1978) 34 figs, 2 tables, 14 refs

Key Words: Lumped parameter methods, Seismic response

New discrete models and their application to seismic response analysis of structures is proposed in this paper. These models consist of finite number of small rigid bodies connected with springs distributed over the contact area of two neighboring bodies. In general size of stiffness matrices of these elements are at most (6 X 6) which are equal to or even smaller than ½ of those of conventional finite elements so that considerable reduction of computing time can be expected. Effectiveness of these elements in nonlinear structural analysis, especially dynamic response analysis of structures are demonstrated by several numerical examples.

78-1744

Torsional Spectrum for Earthquake Motions

W.K. Tso and T.-I. Hsu

Dept. of Civil Engrg. and Engrg. Mechanics, McMaster Univ., Hamilton, Ontario, Canada, Intl. J. Earthquake Engr. Struc. Dynam., <u>6</u> (4), pp 375-382 (July/Aug 1978) 6 figs, 1 table, 7 refs

Key Words: Seismic excitation, Earthquake response, Torsional response, Spectrum analysis, Buildings

A computational scheme is presented to construct forsional spectra due to the rotational component of seismic ground motions. The rotational component of ground motion is estimated from the measured earthquake acceleration records. In contrast to previous studies, no differentiation of acceleration records is involved in the present scheme. The torsional spectrum of the 1940 El Centro earthquake is computed and compared with previous results. An average and a mean plus one standard deviation torsional spectrum is presented for design purposes. These spectra are results based on four historical records (1934 El Centro, 1940 El Centro, 1949 Olympia and 1952 Taft) normalized to the 1940 El Centro intensity.

78-1745

High Earthquake Risk Buildings in New Zealand R. Shepherd

Univ. of Auckland, New Zealand, Intl. J. Earthquake Engr. Struc. Dynam., <u>6</u> (4), pp 383-395 (July/Aug 1978) 9 figs, 2 tables, 8 refs

Key Words: Seismic design, Buildings

Many existing buildings in seismically active areas were constructed prior to the acceptance of any design criteria specifically intended to produce earthquake resistance in the structure. Although such buildings are typically fifty or more years old they still constitute a large proportion of occupied domestic and commercial accommodation. Since almost all these structures comprise greater hazards than more recent constructions they are referred to as High Earthquake Risk buildings. The problems of identification, assessment and alleviation of the deficiencies have received increasing attention in recent years. In this paper some New Zealand experience is recounted.

78-1746

A Reconnaissance Report for the Romanian Earthquake of 4 March 1977

S.S. Tezcan, V. Yerlici, and H.T. Durgunoglu Bogazici Univ., Istanbul, Turkey, Intl. J. Earthquake Engr. Struc. Dynam., <u>6</u> (4), pp 397-421 (July/Aug 1978) 26 figs, 1 table, 15 refs

Key Words: Earthquake damage, Buildings

The engineering aspects of the 4 March 1977 Romanian earthquake are presented. They are based upon a field investigation conducted by the writers in Bucharest and in southern Romania in collaboration with members of the Building Research Institute of Romania, during the period 25-31 March 1977. This report covers general observations, data and evaluation on the character of the earthquake, structural damage inflicted by it, performance of different types of buildings during the earthquake and relief operations.

78-1747

A Model for Formulating Seismic Design Provisions

National Bureau of Standards, Washington, D.C., 10 pp (June 1977)

PB-280 397/1GA

Key Words: Buildings, Earthquake resistant structures

The paper describes a program currently underway in the United States to develop improved seismic design provisions for buildings. Organization of the activity, the form of the provisions and the technical areas included are discussed. Important aspects of the provisions dealing with: design ground motion, structural design, architectural and mechanical-electrical design, and existing buildings are summarized.

SHOCK

(Also see Nos. 1705, 1725, 1726, 1727, 1728, 1797, 1854, 1855, 1881)

78-1748

Evaluation of the Shock Block Technique for Generating Underwater Plane Waves

A.L. Florence and C.M. Romander Sri International, Menlo Park, CA., Rept. No. DNA-4447Z, AD-E300 169, 33 pp (Oct 1977) AD-A053 419/8GA

Key Words: Underwater explosions, Shock wave propagation

Underwater Explosions Research Division has developed a shock block technique for generating underwater plane waves for the Defense Nuclear Agency. The technique was designed to produce a pulse that would simulate the pulse generated by an underwater nuclear explosion and was developed to improve the current method of loading submarine sections in which the energy source is concentrated as either a large sphere or a single line of explosive. This report discusses our work and recommends improvements. Examination of the experimental results revealed that the pulse generated by the equally spaced array of horizontal strands of Primacord explosive forming the shock block was of much shorter duration than predicted by superposition of the pulses from the individual strands. Instead of the required long rectangular pulse, the technique produces a short half-sine wave pulse. The work suggested the use of a helical coil of Primacord wrapped on a disposable cylindrical mandrel as an alternative to the straight strand of Primacord. The coil axis is horizontal and the pitch is the smallest that allows reliable detonation of the complete strand forming the helix without appreciable displacement.

78-1749

Duration of Nuclear Explosion Ground Motion W.W. Hays, K.W. King, and R.B. Park U.S. Geological Survey, Denver Federal Center, Denver, CO 80225, Bull. Seismol. Soc. Amer., <u>68</u> (4), pp 1133-1145 (Aug 1978) 15 figs, 29 refs

Key Words: Nuclear explosion effects, Ground motion

This paper evaluates the duration of strong ground shaking that results from nuclear explosions and identifies some of the problems associated with its determination. Knowledge of the duration of horizontal ground shaking is important out to the epicentral distances of about 44 km and 135 km, the approximate distances at which the ground shaking level falls to 0.01 g for nuclear explosions having yields of about 100 kt and 1,000 kt, respectively. Evaluation of the strong ground motions recorded from the event

STRAIT ($M_L=5.6$) on a linear array of five, broad-band velocity seismographs deployed in the distance range 3.2 to 19.5 km provides information about the characteristics of the duration of ground shaking.

78-1750

Mode and Bound Approximation Methods for Large Deflections of Dynamically Loaded Structures with Plastic and Viscoplastic Behavior

P.S. Symonds

Div. of Engrg., Brown Univ., Providence, RI, 16 pp (Apr 15, 1978) AD-A054 277/9GA

Key Words: Structural response, Pulse excitation, Plastic properties, Viscoplastic properties

The research aimed at finding and developing methods for estimating the main features of response of engineering structures subjected to severe dynamic loading of pulse type, with emphasis put on methods valid both for large deflections and for structures of materials exhibiting strong strain rate sensitivity in the plastic range. Problem types of practical importance include explosive loading, either external due to military attack or internal for example due to disruptive accident in a pressure vessel or containment structure; various types of vehicular impact; wave impact on ship or offshore structures; and high energy rate forming. Preliminary applications have been made of the methods under investigation in the program presently being reviewed in all but the last of the above areas.

GENERAL WEAPON

(See No. 1807)

TRANSPORTATION

(See No. 1732)

PHENOMENOLOGY

DAMPING

(Also see Nos. 1700, 1770, 1836, 1837, 1838, 1839, 1856, 1891)

78-1751

An Experimental Study of the Steady-State Response of Oil-Film Dampers

R.K. Sharma and M. Botman

Pratt & Whitney Aircraft of Canada, Ltd., Longueuil, Quebec, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 216-221 (Apr 1978) 12 figs, 7 refs

Key Words: Fluid-film damping, Oil film bearings, Periodic response

Oil-film dampers are an integral feature of most high-speed, lightweight turbo engines, in which they are used to suppress undesirable shaft dynamic responses. They are generally located at the antifriction main bearings. An experimental study of the steady-state response of an oil-film damper at a main bearing was conducted on the high-speed rig developed for this purpose. The rig and some typical test results on a damper with a discrete number of oil-inlet ports were described in an earlier publication. In this paper, the experimental results are presented on dampers with different geometries and oil-supply arrangements. The results are presented in terms of transmissibility, deflection and damping coefficient plots. The response of the damper with radial springs to simulate gravity effects in a vertical rotor arrangement is compared to that without radial springs.

78-1752

Experimental and Analytical Investigation of Squeeze Film Bearing Damper Forces Induced by Offset Circular Whirl Orbits

P.N. Bansal and D.H. Hibner

Structures Technology Group, Commercial Products Div., Pratt & Whitney Aircraft Group, Div. of United Technologies Corp., East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 549-557 (July 1978) 10 figs, 19 refs

Key Words: Squeeze-film dampers, Hydrodynamic excitation, Whirling

A basic research program was conducted to investigate the hydrodynamic forces of a squeeze film bearing damper. These forces were induced by controlled offset circular whirl orbits of the damper journal. The orbits were mechanically produced by eccentric damper rings and cams in a specially designed, end sealed test rig. Aircraft engine damper geometry and operating conditions were simulated. The instantaneous circumferential pressure profiles, for specific orbits, were measured by eight high response pressure transducers. These test values are required to compare theory with test. Since the data reduction for offset orbits is extremely complicated, this simple method was found to be very useful in analyzing the test results. Test results for pressure profiles as well as damper forces were compared

with theoretical predictions. The analysis is based on "long bearing" solution of Reynolds equation and includes the effect of inlet and cavitation pressures. For the cavitated oil film, inlet pressure was shown to have important effect on damper forces.

78-1753

Analysis and Experimental Investigation of the Stability of Intershaft Squeeze Film Dampers - Part 2: Control of Instability

D.H. Hibner, P.N. Bansal, and D.F. Buono Pratt and Whitney Aircraft, East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 558-562 (July 1978) 8 figs, 5 refs

Key Words: Stability, Squeeze-film dampers, Rotor-bearing systems

A comprehensive stability analysis is used to study the stability of the test rig which incorporates a modified intershaft bearing support. The analysis is applicable to large multi-mass, rotor-bearing systems and includes the effects of gyroscopic moments, shear deformation, bearing support flexibility, and damping. The results of the stability analysis are presented in the form of system stability maps which clearly indicate the effectiveness of the modification in improving the instability onset speed of the system. Also presented are the results of an experimental investigation which substantiate the analytical predictions.

78-1754

Squeeze Film Damper Characteristics for Gas Turbine Engines

R.A. Marmol and J.M. Vance

Government Products Div., Pratt and Whitney Aircraft Group, West Palm Beach, FL, J. Mech. Des., Trans. ASME, 100 (1), pp 139-146 (Jan 1978) 12 figs, 9 refs

Key Words: Squeeze-film dampers, Gas turbine engines, Mathematical models

A mathematical model for squeeze film dampers is developed, and the solution results are compared with data from four different test rigs. A special feature of the analysis is the treatment of several different types of end seals and inlets, with inlet feedback included. A finite difference method is used to solve the Reynolds equation, with a banded matrix inversion routine. The test data are taken from a new high-speed free-rotor rig, and from three previously tested controlled-orbit rigs.

78-1755

The Dynamic Characteristics of O-Rings

A.J. Smalley, M.S. Darlow, and R.K. Mehta Mechanical Technology, Inc., Latham, NY, J. Mech. Des., Trans. ASME, 100 (1), pp 132-138 (Jan 1978) 12 figs. 6 refs

Key Words: Elastomeric dampers, Experimental data

Stiffness and damping characteristics for O-rings are presented and discussed. These characteristics have been determined as a function of frequency and the effect of the following test parameters have been investigated: O-ring material, O-ring cross-section diameter, temperature, amplitude, squeeze, stretch, and groove width. The base excitation, resonant mass method, has been used in conjunction with a computerized system for data acquisition and reduction. Generally consistent data has been obtained and the trends resulting from the parameter changes are, qualitatively, as would be expected.

78-1756

Extinction of Predominantly Subharmonic Oscillations in a Non Linear Dynamic Damper with Two Degrees of Freedom

R. Riganti

Inst. for Rational Mechanics, Polytecnic of Turin, Italy, Mech. Res. Comm., <u>5</u> (3), pp 113-119 (1978) 5 figs, 10 refs

Key Words: Nonlinear damping

Following previous studies on the subharmonic response of forced non linear systems, the steady-state, 1/3 subharmonic oscillations of a dynamic damper with two degrees of freedom, sinusoidal forcing function and viscous dampings are examined. From the analysis, easy theoretical conditions are derived, regarding the limiting values of the various parameters needed to destroy the predominantly subharmonic component in the periodical oscillations of the damper. The results deduced from the proposed conditions are compared with the ones obtained by numerical integration of the equations of motion of the dynamical system.

78-1757

Damping Materials Provide Low-Cost Solutions to Vibration Problems

S/V, Sound Vib., 12 (8), pp 4-7 (Aug 1978)

Key Words: Material damping, Aircraft engines, Airframes

The use of damping materials in aircraft engines and airframes to prevent cracking as a result of vibration is described.

78-1758

Design Evaluation of Layered Viscoelastic Damping Treatments

A.D. Nashif and W.G. Halvorsen Anatrol Corp., Cincinnati, OH, S/V, Sound Vib., 12 (7), pp 12-15 (July 1978) 9 figs, 3 refs

Key Words: Viscoelastic damping, Beams, Structural elements

Design procedures are presented for predicting the performance of viscoelastic vibration damping treatments for application to structures. The results presented are based primarily on the application of damping treatments to simple beams. However, similar procedures have been developed for more complicated systems such as plates and stiffened structures. Correlation between the predicted and measured results using the approach described in the article is very good.

FATIGUE

78-1759

Fatigue Life Prediction of Complex Structures B.N. Leis

Battelle Columbus Labs., Columbus, OH, J. Mech. Des., Trans. ASME, <u>100</u> (1), pp 2-9 (Jan 1978) 4 figs, 52 refs

Key Words: Fatigue life

Because of the complex nature of the fatigue process, it is only recently that reasonably effective analysis procedures for predicting finite-fatigue life for simple notched coupons have evolved. One of the more vexing problems in adapting these procedures to making life predictions for complex components and structures is that of the multiplicity of crack initiation sites and mechanisms which determine the fatigue life of such structures. It has been observed that which of the many potential initiation sites and mechanisms controls failure depends on the service environment and the magnitude and character of the service loading. The present paper critically examines available technology for fatigue analysis of complex structures in which the multiplicity of initiation sites and mechanisms control the structure's life.

78-1760

Dynamic Severity Criterion for Designing Against High Cycle Fatigue

G.S.A. Shawki

Faculty of Engrg., Cairo Univ., Cairo, Egypt, J. Mech. Des., Trans. ASME, 100 (1), pp 10-15 (Jan 1978) 12 figs, 33 refs

Key Words: Fatigue (materials)

A novel approach to the interpretation of material behavior under cyclic loading is presented. In this approach a non-dimensional criterion, featuring the dynamic severity of applied load, is put forward with a view to the provision of simple though confident assessment of component performance under dynamic load. The fatigue diagram based on the proposed criterion displays significant merits over previous diagrams, the presented approach thus providing an effective tool for designing against high cycle fatigue with due consideration to maximum utilization of material.

FLUID

(Also see Nos. 1795, 1810, 1811, 1813, 1875)

78-1761

Aeroelastic Instability of Rectangular Cylinders in a Heaving Mode

K. Washizu, A. Ohya, Y. Otsuki, and K. Fujii Dept. of Aeronautics, Univ. of Tokyo, Tokyo, Japan, J. Sound Vib., <u>59</u> (2), pp 195-210 (July 22, 1978) 16 figs, 11 refs

Key Words: Cylinders, Rectangular bodies, Aeroelasticity, Fluid-induced excitation

This paper deals with wind tunnel experiments on the aeroelastic instability in a heaving mode of two-dimensional rectangular cylinders in a uniform two-dimensional flow. Both the free oscillation method and the forced oscillation method are employed for the experiments. Emphasis is placed on finding the effect of the ratio c/d, which is the ratio of the lengths of the sides of the rectangle, to the aeroelastic instability phenomena in the vicinity of the resonance speed. Emphasis is also placed on finding possible limitations in the application of the quasi-steady aerodynamic theory to the analysis of the aeroelastic characteristics.

78-1762

Extremes of Morison-Type Wave Loading on a Single Pile

G. Moe and S.H. Crandall Massachusetts Inst. of Tech., Cambridge, MA, J. Mech. Des., Trans. ASME, <u>100</u> (1), pp 100-104 (Jan 1978) 3 figs, 9 refs Key Words: Offshore structures, Piles, Water waves, Fluidinduced excitation

A statistical estimate of the extreme wave force perunit length acting on a section of a fixed cylindrical pile in a random sea-state is derived. The random motion of the sea is described by a spectrum of wave heights in conjunction with linear wave theory. The wave force is assumed to depend linearly on the water particle acceleration and nonlinearly on the water velocity according to the Morison formula. The interaction of the velocity and acceleration contributions and the contribution of a small steady current are accounted for by an asymptotic approximation valid for large forces. The expected rate of occurrences of extremes based on a simple peak definition agrees satisfactorily with a more elaborate result based on a true maximum definition. The formulas derived here provide a basis for a design-force procedure which could provide an improvement over the design-wave procedure commonly used for the analysis of offshore structures.

SOIL

78-1763

The Spring Method for Embedded Foundations E. Kausel, R.V. Whitman, J.P. Morray, and F. Elsabee Stone and Webster Engrg. Corp., 245 Summer St., Boston, MA 02107, Nucl. Engr. Des., 48 (2/3), pp 377-392 (Aug 1978) 16 figs, 34 refs

Key Words: Interaction: soil-structure, Spring method

The paper presents simplified rules to account for embedment and soil layering in the soil-structure interaction problem, to be used in dynamic analyses. The relationship between the spring method, and a direct solution (in which both soil and structure are modeled with finite elements and linear members) is presented. It is shown that for consistency of the results obtained with the two solution methods, the spring method should be performed in three steps.

78-1764

Some Aspects of the Ground Vibration Problem T.G. Gutowski, L.E. Wittig, and C.L. Dym Noise Control Engr., 10 (3), pp 94-100 (May-June 1978) 8 figs, 24 refs

Key Words: Ground vibration

The topic of ground vibration involves many disciplines; pertinent work has been done in the areas of seismology, civil engineering, acoustics, noise control, and biomechanics, to mention a few. The purpose of this paper is to draw

together some of these results and to show their applicability to solving ground vibration problems.

78-1765

Soil-Structure Interaction. A Background Discussion for the Swedish Council for Building Research

S. Hansbo and G. Karrholm

Swedish Council for Building Res., Stockholm, Sweden, Rept. No. ISBN-91-540-2719-5; D10:1977, 30 pp (1977)

PB-280 181/9GA

Key Words: Interaction: soil-structure, Reviews

The report investigates damages caused by improper consideration of soil-structure interaction, mechanical properties of soils, mechanical properties of superstructures, computation models, and surveys of research problems.

VISCOELASTIC

(See Nos. 1758, 1796)

EXPERIMENTATION

BALANCING

(Also see No. 1769)

78-1766

Turbine Engine Rotor Dynamic Evaluation. Volume II. Engine and Test Rig Balancing

J. Davis, J. Tessarzik, and R.A. Rio Mechanical Technology, Inc., Latham, NY, Rept. No. MTI-76TR41-VOL-2, AFAPL-TR-76-81-VOL-2, 52 pp (Jan 1978) AD-A054 533/5GA

Key Words: Balancing techniques, Turbine engines

Balancing demonstrations were performed to show the applicability of combining dynamic characteristics and advanced balancing techniques to effectively reduce the vibration of production type machinery. Trim balancing procedures were performed on the TF30, TF41 and F100

jet engines which are currently in use on military aircraft. A very sensitive high-speed experimental test apparatus called the 'Rub Rig' was also used to show the benefits of multiplane-multispeed balancing using influence coefficients.

DIAGNOSTICS

78-1767

Detection of Rolling Element Bearing Damage by Statistical Vibration Analysis

D. Dyer and R.M. Stewart

Mech. Engrg. Labs., G.E.C. Power Engrg., Whetstone, Leicester, UK, J. Mech. Des., Trans. ASME, 100 (2), pp 229-235 (Apr 1978) 9 figs, 16 refs

Key Words: Housings, Bearings, Diagnostic techniques

A new method is presented for predicting rolling element bearing condition from measurements of bearing housing vibration. This method is based on a statistical parameter Kurtosis, that remains constant for an undamaged bearing irrespective of load and speed, yet changes with damage. The extent of damage can be assessed from the distribution of this statistical parameter in selected frequency ranges. An assessment of bearing condition can thus be made with minimum recourse to historical information. Most other damage detection techniques rely heavily on the trend analysis of data and so this new method may prove to be a significant advance in bearing fault detection technology, at least when viewed within the original objective to provide a simple and cheap technique. As with most other simple detection techniques, the precise nature of the fault cannot be defined and for such information it is necessary to use the more sophisticated diagnostic methods.

78-1768

An Evaluation Technique for Determining the Cost Effectiveness of Condition Monitoring Systems

P.T. George and A.T. Parker

Pratt & Whitney Aircraft Group, East Hartford, CT, ASME Paper No. 78-GT-166

Key Words: Diagnostic techniques

A technique for analyzing the cost-effectiveness of condition monitoring systems has been developed both to provide a quantitative assessment of the value of condition monitoring and to guide the selection of items to be monitored by the system. The technique uses historical data combined with catalog cost estimating to estimate both the life cycle cost of the condition monitoring system and the potential cost savings offered by the system for commercial engines. The results are obtained in a form that can be easily con-

verted to any of the primary cost-effectiveness parameters in current use by industry.

78-1769

Turbine Engine Automated Trim Balancing and Vibration Diagnostics

R. McTasney, R.A. Rio, and W.A. Troha Oklahoma City Air Logistics Center, Oklahoma City, OK, ASME Paper No. 78-GT-129

Key Words: Turbine engines, Balancing techniques, Diagnostic techniques

After turbine engine is overhauled at Oklahoma City Air Logistics Center (OC-ALC) or at San Antonio Air Logistic Center (SA-ALC), it is run in the test cell before shipment. While in the test cell, final adjustments are made to the engine. One of these adjustments is the dynamic vibration balance of the engine. This adjustment is referred to as a trim balance. The current trim balance procedures in use at OC-ALC require the engine to be in the test cell from 4 to 6 hours.

78-1770

Signature Analysis of Acoustic Emissions From Composites. Final Report. 1 Oct 1975 - 30 Mar 1978 E.G. Henneke, II

Dept. of Engrg. Science and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA., Rept. No. NASA-CR-145373, 79 pp (May 19, 1978) N78-23148

Key Words: Acoustic signatures, Fracture properties, Composite materials

Acoustic emission data were obtained from a series of tensile tests on specially designed graphite-epoxy unidirectional laminates. The design was such that the specimens would preferentially fail first by fiber breakage and later by matrix splitting. The AE signals for each of these events was analyzed and some typical results are reported. Patterns characteristic of each failure mechanism were noted for both the time signatures and the corresponding frequency spectra.

EQUIPMENT

(See Nos. 1724, 1837)

INSTRUMENTATION

(Also see No. 1715)

78-1771

Frequency Spectrum Analyzer

M.J. Post, R.E. Cupp, and R.L. Schwiesow Wave Propagation Lab., National Oceanic and Atmospheric Adminstration, Boulder, CO, Rept. No. NOAA-TR-ERL-392, WPL-51, 8 pp (Oct 1976) PB-280 941/6GA

Key Words: Frequency analyzers

The report describes an electronic apparatus that analyzes Doppler returns from an infrared lidar system. By processing each spectral frequency channel with a 100 percent duty cycle rather than with a swept filter analyzer, considerably better S/N is obtained.

78-1772

Industrial Sound Level Meter Environmental Testing

R.J. Koshut

Testing and Certification Branch, National Inst. for Occupational Safety and Health, Morgantown, WV, Rept. No. NIOSH/TC/P-015, 35 pp (Apr 1978) PB-280 028/2GA

Key Words: Sound level meters, Environmental effects

This test procedure checks the effect on an industrial sound level meter when it is subjected to environmental conditions of temperature and humidity. Included is a list of equipment needed to perform the test and the configuration in which the equipment is to be used.

TECHNIQUES

(See Nos. 1713, 1715, 1736)

COMPONENTS

ABSORBERS

78-1773

Physical and Acoustical Properties of Urethane Foams

E. O'Keefe

Specialty Composites Corp., Newark, DE, S/V, Sound Vib., 12 (7), pp 16-21 (July 1978) 7 figs, 3 tables, 12 refs

Key Words: Foams, Acoustic properties, Vibration dampers, Acoustic absorption, Noise barriers

The basic processes governing the manufacturing of acoustical foams, as well as the physical properties which affect their use as an acoustic absorber, barrier, or vibration damper are described. Some of the properties which determine the acoustical properties are the flow resistance, thickness, type of facing, stiffness, and even temperature. The relevance of different methods for determining acoustical performance are discussed, and methods are recommended for specifying some of the important acoustic parameters of acoustical foams.

SHAFTS

(See Nos. 1834, 1892)

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 1723, 1789)

78-1774

The Dynamics and Control of Large Flexible Space Structures. Part A: Discrete Model and Modal Control P.M. Bainum and R. Sellappan

Dept. of Mech. Engrg., Howard Univ., Washington, D.C., Rept. No. NASA-CR-156975, 59 pp (May 1978)

N78-23139

Key Words: Spacecraft, Beams, Mathematical models, Lumped parameter methods, Modal control technique

Attitude control techniques for the pointing and stabilization of very large, inherently flexible spacecraft systems were investigated. The attitude dynamics and control of a long, homogeneous flexible beam whose center of mass is assumed to follow a circular orbit was analyzed. First order effects of gravity gradient were included. A mathematical model which describes the system rotations and deflections within the orbital plane was developed by treating the beam as a number of discretized mass particles connected by massless, elastic structural elements. The uncontrolled dynamics of the system are simulated and, in addition, the effects of the control devices were considered. The concept of distributed modal control, which provides a means for controlling a system mode independently of all other modes, was examined. The effect of varying the number of modes in the model as well as the number and location of the control devices were also considered.

78-1775

The Dynamics and Control of Large Flexible Space Structures. Part B: Development of Continuum Model and Computer Simulation

P.M. Bainum, V.K. Kumar, and P.K. James Dept. of Mech. Engrg., Howard Univ., Washington, D.C., Rept. No. NASA-CR-156976, 116 pp (May 1978)

N78-23140

Key Words: Spacecraft, Beams, Mathematical models, Computerized simulation, Equations of motion

The equations of motion of an arbitrary flexible body in orbit were derived. The model includes the effects of gravity with all its higher harmonics. As a specific example, the motion of a long, slender, uniform beam in circular orbit was modeled. The example considers both the inplane and three dimensional motion of the beam in orbit. In the case of planar motion with only flexible vibrations, the pitch motion is not influenced by the elastic motion of the beam. For large values of the square of the ratio of the structural modal frequency to the orbital angular rate the elastic motion was decoupled from the pitch motion. However, for small values of the ratio and small amplitude pitch motion, the elastic motion was governed by a Hill's 3 term equation. Numerical simulation of the equation indicates the possibilities of instability for very low values of the square of the ratio of the modal frequency to the orbit angular rate. Also numerical simulations of the first order nonlinear equations of motion for a long flexible beam in orbit were performed. The effect of varying the initial conditions and the number of modes was demonstrated.

78-1776

On the Multiplicity of Solutions of the Inverse Problem for a Vibrating Beam

V. Barcilon

Dept. of Geophysical Sciences, Chicago, Univ., IL, 19 pp (Apr 1978) AD-A054 248/0GA

Key Words: Beams, Spectrum analysis

The 2 to the N-1 power fold multiplicity of solutions found by Boley and Golub in their study of the inverse problem for N X N symmetric, pentadiagonal matrices contrasts with the unicity of the solution of the inverse problem for an inhomogeneous, discrete beam.

78-1777

Minimum Mass Structures with Specified Natural Frequencies

A. Miele

Aero-Astronautics Group, Rice Univ., Houston, TX, Rept. No. AAM-WP-1, AFOSR-TR-78-0751, 27 pp (1976)

AD-A053 727/4GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated numerically. The mass distribution that minimizes the total mass for a given fundamental frequency constraint is determined using both the sequential ordinary gradient-restoration algorithm (SOGRA) and an ad hoc modification of the modified quasilinearization algorithm (MQA).

78-1778

Numerical Determination of Minimum Mass Structures with Specified Natural Frequencies

A. Miele, A. Mangiavacchi, B.P. Mohanty, and A.K. Wu

Aero-Astronautics Group, Rice Univ., Houston, TX, Rept. No. AAR-138, AFOSR-TR-78-0723, 64 pp (1977)

AD-A053 725/8GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated both analytically and numerically. The mass distribution that minimizes the total mass for a given value of the frequency parameter beta is determined using both the sequential ordinary gradient-restoration algorithm (SO-GRA) and the modified quasilinearization algorithm (MQA). Concerning the minimum value of the mass, SOGRA leads to a solution precise to at least 4 significant digits and MQA leads to a solution precise to at least 6 significant digits. Comparison of the optimal beam (a variable-section beam) with a reference beam (a constant-section beam) shows that the weight reduction depends strongly on the frequency parameter beta.

78-1779

Some Qualitative Considerations on the Numerical Determination of Minimum Mass Structures with Specified Natural Frequencies

A. Mangiavacchi and A. Miele

Aero-Astronautics Group., Rice Univ., Houston, TX, Rept. No. AAM-WP-2, AFOSR-TR-78-0724, 17 pp (1977)

AD-A053 726/6GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated analytically. The range of values of the frequency parameter having technical interest is determined.

78-1780

Traveling Loads on the Timoshenko Beam

P.J. Torvik

Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT-TR-78-2, 42 pp (Apr 1978) AD-A054 628/3GA

Key Words: Beams, Timoshenko theory, Moving loads, Critical speeds

A transverse force traveling along an infinite string or a beam at critical values of constant velocity generates unbounded amplitudes, in the absence of dissipation. This resonance is analogous to the unbounded amplitudes generated by a stationary force oscillating at one of the natural frequencies. The response of a finite elementary beam to a moving force of constant amplitude can be determined in terms of the eigenfunctions of the beam. Modification of elementary beam theory to take into account the effects of rotatory inertia and shear leads to the Timoshenko beam theory, from which a new set of eigenvalues and eigenfunctions can be determined. These eigenfunctions can be shown to have an orthogonality relationship which, although unusual, permits the solution of initial value and non-homogeneous problems. The procedure for solving such problems is given, and applied to the problem of a traveling load on a finite Timoshenko beam with arbitrary end conditions. Results are obtained for the case of pinned ends, and compared with those from elementary theory.

78-1781

Vibration of an Elastic Beam Subjected to Discrete Moving Loads

M. Kurihara and T. Shimogo

Faculty of Engrg., Keio Univ., Yokohama, Japan, J. Mech. Des., Trans. ASME, 100 (3), pp 514-519 (July 1978) 6 figs, 6 refs

Key Words: Beams, Moving loads, Random excitation, Poisson's ratio, Time-dependent excitation, Spectral energy distribution techniques

In this paper, vibration problems of a simply-supported elastic beam subjected to randomly spaced moving loads with a uniform speed are treated under the assumption that the input load sequence is a Poisson process. In the case in which the inertial effect of moving loads in neglected,

the time history, the power spectral density, and the various moments of the response are examined and the effects of the speed of moving loads upon the beam are made clear.

78-1782

Stability of a Simply-Supported Beam Subjected to Randomly Spaced Moving Loads

M. Kurihara and T. Shimogo

Faculty of Engrg., Keio Univ., Yokohama, Japan, J. Mech. Des., Trans. ASME, 100 (3), pp 507-513 (July 1978) 7 figs, 7 refs

Key Words: Beams, Moving loads, Random excitation, Poisson's ratio, Inertial forces, Coriolis forces

In this paper, vibration problems of a simply-supported elastic beam subjected to randomly spaced moving loads with a uniform speed are treated under the assumption that the input load sequence is a Poisson process. In the case in which the inertial effect of moving loads is taken into account, the stability problem relating to the speed and the mass of loads is dealt with, considering the inertia force, the centrifugal force, and the Coriolis force of the moving loads. As an analytical result a stability chart of the mean-squared deflection was obtained for the moving speed and the moving masses.

78-1783

The Vibration Characteristics of a Beam with an Axial Force

R.E.D. Bishop and W.G. Price

Dept. of Mech. Engrg., Univ. College London, London WC1E 7JE, UK, J. Sound Vib., <u>59</u> (2), pp 237-244 (July 22, 1978) 2 figs, 4 refs

Key Words: Beams, Equations of motion, Timoshenko theory

Equations of motion are found for a non-uniform damped Timsohenko beam with a distributed axial force. Principal modes may be extracted by numerical means when the boundary conditions are specified, and the appropriate orthogonality conditions are given. The theory of linear forced vibration can thus be derived. It is an implicit requirement that all axial forces are conservative.

78-1784

Vibrations of Continuous Timoshenko Beams on Winkler-Pasternak Foundations

T.M. Wang and L.W. Gagnon

Dept. of Civil Engrg., Univ. of New Hampshire,

Durham, NH 03824, J. Sound Vib., <u>59</u> (2), pp 211-220 (July 22, 1978) 7 figs, 7 refs

Key Words: Beams, Timoshenko theory, Rotatory inertia effects, Transverse shear deformation effects

The dynamic analysis of continuous Timoshenko beams on Winkler-Pasternak foundations by means of the general dynamic slope-deflection equations is presented. A three-span continuous beam on a Winkler-Pasternak foundation subjected to free and forced vibrations is used to illustrate the application of the proposed method and to show the effects of rotary inertia, transverse-shear deformation and foundation constants on the beam.

78-1785

Parametric Study of Free Vibration of Sagged Cables M.L. Gambhir and B. deV. Batchelor

Queen's Univ. at Kingston, Ontario, Canada, Computers Struc., <u>8</u> (5), pp 641-648 (May 1978) 8 figs, 10 refs

Key Words: Cables (ropes), Natural frequencies, Mode shapes, Finite element technique, Parametric excitation

The finite element method is applied to the study of natural frequencies and modes of vibration of sagged cables. Extensional characteristics of the element are fully considered. The method is applied to a numerical example taken from the literature and which has previously been analyzed by classical and other methods. The results obtained by the use of a straight element are compared with those obtained by the use of curved elements. Finally, a parametric study is conducted to determine the influence of various parameters on the spectrum of natural frequencies of a sagged cable and appropriate nondimensional curves are presented. These non-dimensional curves give an insight into the general characteristics of the sagged cable, and can be used to predict in-plane natural frequencies over a wide range of sag/span ratio.

BEARINGS

(Also see Nos. 1751, 1767)

78-1786

Elastomeric Bearings Don't Slide or Roll

J.R. Potter

Lord Kinematics, Lord Corp., Erie, PA, Power Transm. Des., 20 (7), pp 38-40 (July 1978) 11 figs

Key Words: Elastomeric bearings

Elastomeric bearings serve well in oscillatory or reciprocating motion applications. They require no lubrication and the functions of several bearing types can often be combined in one bearing, thus simplifying a design. This article presents the various types of elastomeric bearings and their operating principles.

78-1787

Single-Row Sphericals: Less Bearing, Longer Life

Bearing Div., McGill Mfg. Co., Valparaiso, IN, Power Transm. Des., 20 (7), pp 35-37 (July 1978) 6 figs

Key Words: Roller bearings

Specialists in bearing technology have long recognized the performance advantages of single-row spherical roller bearings, which accommodate large shaft deflection and misalignment to \pm 3°. The article discusses an application of single-row sphericals and two applications where one row was better than two.

BLADES

(Also see No. 1895)

78-1788

Vibration Characteristics of Hollow Symmetrical Blades Based on Thin Shell Theory

A.M. Al Jumaily and L.L. Faulkner
Dept. of Mech. Engrg., Ohio State Univ., Columbus,
OH, J. Mech. Des., Trans. ASME, 100 (1), pp 183187 (Jan 1978) 5 figs, 4 tables, 9 refs

Key Words: Turbomachinery blades, Blades, Shells, Natural frequencies

This paper presents the results of investigating the vibrational characteristics of a hollow symmetrical blade based on thin shell theory which allows closed function representation of vibrational characteristics which are inaccessible using beam theory. A modified shell theory is presented and used for the analysis. This technique is used to express the results in a continuous function analytical formation. The method presented is clearly for long hollow blades and does not require the computer storage of numerical methods. Comparison is made between the present technique, the beam theory, and experimental data for two laboratory models. The formulation can be extended to most types of blades and still retain the functional representation.

78-1789

Comparison of Some Optimal Control Methods for the Design of Turbine Blades

B.M.E. de Silva and G.N.C. Grant

Aircraft Aerodynamics Branch, Aerodynamics Div., Ames Res. Center, NASA, Moffett Field, CA, J. Mech. Des., Trans. ASME, 100 (1), pp 173-182 (Jan 1978) 2 figs, 3 tables, 48 refs

Key Words: Turbine blades, Structural synthesis, Optimization, Numerical methods, Timoshenko theory

This paper attempts a comparative study of some numerical methods for the optimal control design of turbine blades whose vibration characteristics are approximated by Timoshenko beam idealizations with shear and incorporating simple boundary conditions. The blade was synthesized using the following methods: conjugate gradient minimization of the system Hamiltonian in function space incorporating penalty function transformations, projection operator methods in a function space which includes the frequencies of vibration and the control function, &technique penalty function transformation resulting in a highly nonlinear programming problem, finite difference discretization of the state equations again resulting in a nonlinear program, second variation methods with complex state differential equations to include damping effects resulting in systems of inhomogeneous matrix Riccatti equations some of which are stiff, and quasi-linear methods based on iterative linearization of the state and adjoint equation. The paper includes a discussion of some substantial computational difficulties encountered in the implementation of these techniques together with a resume of work presently in progress using a differential dynamic programming approach.

78-1790

Experimental Study on Blade Bending Vibration

T. Matsuura

Dept. of Engrg., Cambridge Univ., UK, Rept. No. CUED/A-Turbo/TR-88; ISSN-0309-6521, 32 pp (1977) N78-23090

Key Words: Compressor blades, Flexural vibration, Vibration prediction, Experimental data

Experiments were performed on the forced vibration of cascade blades due to the upstream periodic wakes. The resonance vibration amplitude and phase of the 1st bending mode were measured in a compressor rotor with the h/t ratio of 0.4. Smith's unsteady lift coefficients were used, and the mechanical damping of the blade was introduced to predict the resonance amplitude and phase. Reasonable agreement was seen between the measured results and the prediction.

Aerodynamic Phenomena in an Oscillating Transonic MCA Airfoil Cascade Including Loading Effects

S. Fleeter and R.E. Riffel

Detroit Diesel Allison, Indianapolis, IN, In: AGARD Unsteady Aerodyn., 16 pp (Feb 1978) N78-22066

Key Words: Fan blades, Aerodynamic response

The steady, quasi-steady, and unsteady aerodynamics were determined for a multiple circular arc (MCA) airfoil cascade which modeled the tip section of an advanced design fan blade. The steady airfoil surface aerodynamic performance of the cascade was measured at two levels of aerodynamic loading and correlated with the predictions from a time-marching, steady, transonic flow analysis. The chordwise distribution of the quasi-static unsteady pressure coefficient for a 0 deg interblade phase angle was determined and correlated with two appropriate predictions: one based on the steady transonic analysis and the other on steady inviscid supersonic flat plate theory. Finally, the MCA cascade was harmonically oscillated in the torsional mode at a reduced frequency value of 0.14. The fundamental unsteady aerodynamic data was obtained at a Mach number equal to 1.55 over a range of interblade phase angles for two values of the cascade static pressure ratio. Results were correlated with the predictions from state-of-the-art unsteady flat plate cascade analyses.

78-1792

Dynamic Analysis of an Assembly of Shrouded **Blades Using Component Modes**

A.V. Srinivasan, S.R. Lionberger, and K.W. Brown Commercial Products Div., Pratt & Whitney Aircraft, United Technologies Corp., East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 520-527 (July 1978) 11 figs, 3 tables, 9 refs

Key Words: Shrouds, Fan blades, Component mode synthesis, Vibration response

The problem of vibratory behavior of an assembly of shrouded fan blades is examined. The point of view that forms the basis for the analysis is that the vibration characteristics of an assembly of blades can be predicted from a knowledge of vibration characteristics of its components. Clearly, linear behavior is assumed. A viscous type of damping mechanism is included to account for any energy dissipation due to vibratory rubbing action at shroud interfaces. As the component modes are computed with a single blade and shroud modeled with plate elements, the extent of chordwise motion in different modes is examined. Numerical results of an application of the analysis to a typical fan design are included.

78-1793

Synthesis of Blade Flutter Vibratory Patterns Using Stationary Transducers

A. Kurkov and J. Dicus

Lewis Res. Center, NASA, Cleveland, OH, ASME Paper No. 78-GT-160

Key Words: Blades, Flutter

Flutter frequency was determined and rotor vibratory amplitude and phase distributions during flutter were reconstructed from stationary aerodynamic type measurements. A previously reported optical method for measuring blade-tip displacements during flutter was extended by means of digital analysis. Displacement amplitudes and phase angles were determined based on this method. For selected blades, spectral results were also obtained from strain gage measurements. The results from these three types of measurement were compared and critically evaluated.

78-1794

Vibrations of Cambered Helicoidal Fan Blades K.P. Walker

Pratt & Whitney Aircraft, East Hartford, CT 06108, J. Sound Vib., 59 (1), pp 35-57 (July 8, 1978) 9 figs, 12 tables, 30 refs

Key Words: Fans, Blades, Shells, Natural frequencies, Mode shapes, Transverse shear deformation effects, Rotatory inertia effects

A conforming finite shell element suitable for the analysis of curved twisted fan blades is developed and applied to a number of fan blade models. The element is assumed to be a doubly curved right helicoidal shell, in which the curvature is shallow with respect to the twisted base plane defining the helicoid. Element stiffness and mass formulations are based on Mindlin's theory and include the effects of transverse shear and rotary inertia. The thick shell element has 64 generalized co-ordinates, and by deleting transverse shear effects, a thin shell version of the element having 40 generalized co-ordinates is obtained. The thin shell element is used to predict the natural frequencies and mode shapes of a number of fabricated fan blade structures and the results are correlated with experiment.

CONTROLS

An Analysis of the Three-Way Underlapped Hydraulic Spool Servovalve

C.K. Taft and J.P. Twill

Dept. of Mech. Engrg., Univ. of New Hampshire, Durham, NH, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 117-123 (June 1978) 11 figs, 11 refs

Hydraulic servomechanisms, Valves, Fluid-Key Words: induced excitation, Mathematical models

A flow model of a three-way underlapped hydraulic servovalve is presented and used to derive a mathematical description of the flow momentum forces acting on the valve spool. The effect of these forces on valve performance is investigated by examining both the linearized system differential equations and digital computer solutions of the system nonlinear differential equations, and by experimental measurements. A three-dimensional phase space is used to display computer simulation results. Because of the oscillatory nature of system response, projections on a plane illustrate system dynamic response forms. The effects of system parameters on system stability are discussed.

CYLINDERS

78-1796

Dynamic Response of a Geometrically Nonlinear Elastic/Viscoelastic Cylinder

A.J.K. Neighbors

Ph.D. Thesis. The Univ. of Alabama, 173 pp (1977) UM 7809870

Key Words: Cylinders, Composite structures, Viscoelasticcore containing media, Impact response

This work is concerned with the dynamic analysis of an infinitely long circular composite cylinder with a viscoelastic core and a thin elastic case. The thin elastic case serves as the principal load carrying structure while the viscoelastic core contributes mass and damping effects to the dynamic behavior. The cylinder is subjected to a uniform internal static pressure and an externally distributed impulse load.

78-1797 **Shock Induced Structural Response**

J.G. Gallo

Naval Postgraduate School, Monterey, CA, 58 pp (Mar 1978) AD-A053 877/7GA

Key Words: Cylinders, Submerged structures, Interaction: structure-fluid, Shock response

An infinitely long, ring-stiffened, submerged, elastic cylinder having uniformly spaced elastic bulkheads is considered. Loading is applied by a plane acoustic shock wave with front parallel to the cylinder axis. Dynamic pressure in the fluid is resolved into a free-field incident part and a scattered part. Structural response and scattered pressure in the surrounding fluid are found using finite element modeling of structure and fluid. Introduction of Fourier series makes the fluid region mathematically two-dimensional. A radiation, or nonreflecting, condition at the outer boundary of the fluid region is shown to give good results. A parametric study is made of effects of shock pulse rise time and duration on structural response. Results are presented as combinations of shock pressure and submergence pressure just sufficient to induce structural failure.

DUCTS

(Also see Nos. 1735, 1767)

78-1798

High Frequency Sound Attenuation in Short Flow Ducts

J.W. Posev

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-78708, 25 pp (May 1978) N78-23876

Key Words: Ducts, Sound attenuation, High frequencies, Acoustic linings

A geometrical acoustics approach is proposed as a practical design tool for absorbent liners in such short flow ducts as may be found in turbofan engine nacelles. As an example, a detailed methodology is presented for three different types of sources in a parallel plate duct containing uniform ambient flow. A plane wave whose wavefronts are not normal to the duct walls, an arbitrarily located point source, and a spatially harmonic line source are each considered. Optimal wall admittance distributions are found, and it is shown how to estimate the insertion loss for any admittance distribution.

FRAMES, ARCHES

78-1799

Computer-Aided Optimum Seismic Design of Ductile Reinforced Concrete Moment-Resisting Frames

S.W. Zagajeski and V.V. Bertero

Earthquake Engrg. Res. Center, California Univ., Richmond, CA, Rept. No. UCB/EERC-77/16, 146 pp (Dec 1977)

PB-280 137/1GA

Key Words: Seismic design, Computer-aided techniques, Framed structures, Multistory buildings, Concrete

A computer-aided design procedure based on limit state design concepts is proposed for multistory reinforced concrete frames of buildings which are expected to experience severe earthquake ground shaking during their service life. In this procedure a structure is designed to meet various serviceability criteria under service loading conditions, damage limitations for abnormal environmental conditions, and safety requirements for extreme earthquake excitations. The design procedure, which makes use of computer optimization methods as well as static and dynamic elastic and nonlinear analysis procedures, consists in five basic steps which are grouped into a preliminary design phase and a final design phase.

78-1800

Spatial Symmetrical Vibrations and Stability of Circular Arches with Flexibly Supported Ends Y. Wasserman

Dept. of Mech. Engrg., Ben Gurion Univ. of the Negev, Beersheva, Israel, J. Sound Vib., <u>59</u> (2), pp 181-194 (July 22, 1978) 7 figs, 3 tables, 10 refs

Key Words: Arches, Fundamental frequencies

In this work, exact formulae have been obtained for determining the lowest natural frequencies and critical loads of elastic circular arches with flexibly supported ends for symmetrical vibration in the direction perpendicular to the initial curvature of the arch. This investigation is concerned with three cases of load behavior during the process of deformation. The values of the frequencies and critical loads are shown to be dependent on the opening angle of the arch, on the stiffness of the flexibly supported ends and on the ratio of the flexural rigidity to the torsional rigidity of the arch cross-section.

GEARS

78-1801

Simulation of Resonances and Instability Conditions in Pinion-Gear Systems

M. Benton and A. Seireg

Dept. of Mech. Engrg., Univ. of Wisconsin, Madison, WI, J. Mech. Des., Trans. ASME, 100 (1), pp 26-32 (Jan 1978) 9 figs, 16 refs

Key Words: Gears, Periodic excitation, Periodic response, Stiffness, Computerized simulation

This paper describes a computer simulation procedure based on the phase-plane method for predicting the steady-state response, resonances and instabilities of pinion-gear systems subjected to sinusoidal excitation. An experimental technique is also presented which is capable of checking the accuracy of the simulation under different operating conditions. The experimental set-up which utilizes a shaker for producing variations of mesh stiffness without complete rotation of the gear pair provides a relatively simple and convenient means for investigating this class of problems.

78-1802

Stress Condition, Vibrational Exciting Force, and Contact Pattern of Helical Gears with Manufacturing and Alignment Error

A. Kubo

Kyoto Inst. of Tech., Matsugasaki, Kyoto, Japan, J. Mech. Des., Trans. ASME, 100 (1), pp 77-84 (Jan 1978) 9 figs, 12 refs

Key Words: Helical gears, Spur gears, Gears, Geometric imperfection effects

The general method for calculation of load sharing to every tooth pair in meshing, load distribution, and contact pattern on tooth flank of helical gears with manufacturing and alignment error is shown, for which some parts of tooth flanks on the geometrical line of contact can separate from each other due to the errors. For such gears, stiffness of meshing tooth pair, exciting force of gear vibration, and total composite error (single flank) under loaded condition is derived. Using this calculating method, tooth stiffness, vibration excitation, tooth fillet stress, and contact pattern are calculated for some helical and spur gears, and they are compared with measured results.

78-1803

Dynamic Tooth Loads and Stressing for High Contact Ratio Spur Gears

R.W. Cornell and W.W. Westervelt Hamilton Standard, Div. of United Technologies Corp., Windsor Locks, CT, J. Mech. Des., Trans. ASME, 100 (1), pp 69-76 (Jan 1978) 13 figs, 2 tables, 10 refs

Key Words: Spur gears, Mathematical models, Computer programs

A time history, closed form solution is presented for a dynamic model of spur gear systems for all practical contact ratios. The analysis determines the dynamic response of the gear system and the associated tooth loads and stressing. The dynamic model is based on work done by Richardson

and Howland and assumes the two gears act as a rigid inertia and the teeth act as a variable spring of a dynamic system excited by the meshing action of the teeth. Included in the analysis are the effects of the nonlinearity of the tooth pair stiffness during mesh, the tooth errors, and the tooth profile modifications. Besides reviewing the features, solution, and program of this analysis, preliminary results from applying the analysis are presented, which show that tooth profile modification, system inertia and damping, and system critical speeds can affect the dynamic gear tooth loads and stressing significantly.

78-1804

Design Synthesis of a Multi-Speed Machine Tool Gear Transmission Using Multiparameter Optimization

M.O.M. Osman, S. Sankar, and R.V. Dukkipati Concordia Univ., Montreal, Quebec, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 303-310 (Apr 1978) 12 figs, 2 tables, 6 refs

Key Words: Power transmission systems, Gear drives, Machine tools, Structural synthesis, Optimization

This paper presents a novel method for the design synthesis of a multi-speed machine tool gear drive using a multi-parameter optimization technique. The method eliminates any complex and tedious algebraic analysis normally required in gear train designs. It requires only the formulation of mesh and speed ratio equations from the geometrical arrangement of the gear drive and the selection of a suitable optimization criterion and constraints.

LINKAGES

78-1805

An Experimental and Analytical Study of Impact Forces in Elastic Mechanical Systems with Clearances

S. Dubowsky and M.F. Moening Univ. of California, Los Angeles, CA 90024, Mech. Mach. Theory, 13 (4), pp 451-465 (1978) 14 figs, 1 table, 25 refs

Key Words: Joints (junctions), Impact response

Important performance limitations in mechanical systems result from correction clearances which cause rapid wear, and increased noise and vibration. Relatively little experimental investigation has been performed in this area, although a number of analytical studies have been carried out. Recent studies of the latter kind show the effect of clearances is

to amplify, greatly, connection forces, and that the introduction of link flexibility tends to reduce these impact forces significantly. This study shows experimentally the validity of the analytical studies and the mitigating effects of link flexibility on impact forces.

78-1806

Dynamics of High-Speed Linkages with Elastic Members

A. Midha

Ph.D. Thesis, Univ. of Minnesota, 167 pp (1977) UM 7809704

Key Words: Linkages, Periodic response, Transient response

A great deal of attention has been given to the areas of analysis and synthesis of linkages with elastic members within the past fifteen years. Recently, kinematicians have turned to the use of structural dynamics analysis techniques for ease in handling complex linkage systems on computers. With a very few exceptions, little attention has been given to the economy of the computational methods. In this dissertation, after developing the equations of motion for a representative four-bar crank-rocker linkage, two computationally efficient numerical methods are generated. One method computes directly the periodic response, while the other is adaptable to the transient response analysis of the high-speed linkage.

MECHANICAL

78-1807

Sensitivity Analysis and Optimal Design of a Mechanical System with Intermittent Motion

R.C. Huang, E.J. Haug, Jr., and J.G. Andrews Div. of Materials Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 100 (3), pp 492-499 (July 1978) 6 figs, 1 table, 11 refs

Key Words: Intermittent motion, Weapons systems, Optimization, Steepest descent method

In this paper, a specific weapon recoil mechanism is treated in order to illustrate the problem class, to allow for development of a method of solution, and to provide a practical test of the method. A steepest descent optimization method, developed for mechanical design applications is employed to solve illustrative optimal design problems. Generalizations of the method will be treated in a future paper.

Evaluation of Mutual Radiation Impedances Between Circular Pistons by Impulse Response and Asymptotic Methods

P.R. Stepanishen

Dept. of Ocean Engrg., Univ. of Rhode Island, Kingston, RI 02881, J. Sound Vib., <u>59</u> (2), pp 221-235 (July 22, 1978) 7 figs, 1 table, 14 refs

Key Words: Pistons, Impact response (mechanical)

A general approach is presented to evaluate the mutual radiation impedance between circular pistons of arbitrary size and spacing in an infinite rigid planar baffle. The impedance is expressed as a Fourier transform of a generalized impulse response which is defined by an integral relationship. Although the integral must, in general, be numerically evaluated, several special cases of interest can readily be evaluated by using asymptotic techniques. Several asymptotic expressions for the mutual radiation impedance are developed and their limitations are noted. Numerical results are then presented for the generalized impulse response and mutual radiation impedance corresponding to pistons of equal size and arbitrary spacing.

PIPES AND TUBES

78-1809

Forced Vibration of Continuous System with Nonlinear Boundary Conditions

T Watanabe

Faculty of Education, Yamanashi Univ., Kofu, Japan, J. Mech. Des., Trans. ASME, 100 (3), pp 487-491 (July 1978) 6 figs, 13 refs

Key Words: Piping, Nuclear reactor components, Forced vibration, Continuous beams

This paper deals with the nonlinear vibration problem concerning mechanical equipment-piping systems in nuclear power plants and others. An analytical method by approximate solutions is introduced for these systems as a continuous system with nonlinear boundary conditions, and some numerical examples are shown. Finally some numerical results obtained as a continuous system are compared with those of a single-degree-of-freedom system.

78-1810

Cross-Flow Induced Vibrations in a Tube Bank - Vortex Shedding

L.K. Grover and D.S. Weaver

Dept. of Mech. Engrg., Rochester Inst. of Tech., Rochester, NY, J. Sound Vib., <u>59</u> (2), pp 263-276 (July 22, 1978) 9 figs, 1 table, 16 refs

Key Words: Tubes, Heat exchangers, Fluid-induced excitation, Vortex shedding

An experimental wind-tunnel facility which was developed specifically to study cross-flow induced vibrations in heat exchanger tube banks is described. Nineteen tubes in the center of the closely packed array were flexibly mounted in order that their response and interaction with the flow could be studied. The surrounding 116 tubes were fixed and could be easily removed to study the effect of tube bundle size on flow phenomena and tube response. Results are presented in this paper for vortex shedding.

78-1811

Cross-Flow Induced Vibrations in a Tube Bank --Turbulent Buffeting and Fluid Elastic Instability D.S. Weaver and L.K. Grover

Dept. of Mech. Engrg., McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., <u>59</u> (2), pp 277-294 (July 22, 1978) 14 figs, 21 refs

Key Words: Tubes, Heat exchangers, Fluid-induced excitation, Turbulence

Experimental results are reported for a wind tunnel study of cross-flow induced vibrations in a tube bank. The rotated triangular array had a pitch ratio of 1.375 and consisted of 19 flexibly mounted tubes surrounded by 116 rigid, removable tubes. The natural frequency and damping of the flexibly mounted tubes could be carefully controlled. Details of the experimental facility and the vortex shedding behavior of the tube bank were reported in the first of these two companion papers. The turbulent buffeting and fluid elastic response are treated in this second paper. The effects on the fluid elastic threshold of the motion of surrounding tubes, damping and number of upstream rows of tubes are discussed.

78-1812

Dispersive Effects in Wave Propagation in Thin-Walled Elastic Tubes

T.B. Moodie and J.B. Haddow Dept. of Mathematics, Univ. of A

Dept. of Mathematics, Univ. of Alberta, Edmonton, Alberta, Canada T6G 2E1, J. Acoust. Soc. Amer., 64 (2), pp 522-528 (Aug 1978) 12 figs, 5 refs

Key Words: Elastic waves, Wave propagation, Tubes, Elastomers, Fluid-induced excitation

A simple procedure, based on Love's approximate theory [The Mathematical Theory of Elasticity (Cambridge U.P., Cambridge, England, 1927), 4th ed.] for wave propagation in a bar, is proposed in order to consider dispersive effects in wave propagation in a thin-walled, fluid-filled, elastomer tube. It is assumed that the perturbation from steady flow in the tube is small enough that a linearized theory is valid, and that the elastic modulus of the tube is small compared with the bulk modulus of the fluid so that compressibility of the fluid can be neglected. The flexural rigidity of the tube wall, the inertia of the tube wall, and the radial inertia of the fluid are taken into account, and an approximate expression for the dispersion relation for the fundamental mode is obtained.

78-1813

Experiments on Fluidelastic Vibration of Cantilevered Tube Bundles

S.S. Chen and J.A. Jendrzejczyk
Components Tech. Div., Argonne National Lab.,
Argonne, IL, J. Mech. Des., Trans. ASME, 100
(3), pp 540-548 (July 1978) 9 figs, 6 tables, 3 refs

Key Words: Tubes, Fluid-induced excitation, Interaction: structure-fluid, Coupled response, Periodic response, Natural frequencies, Mode shapes

This paper presents the results of three series of experiments on coupled tube/fluid vibration. Natural frequencies and mode shapes of coupled modes as well as steady-state responses are measured for each tube bundle. An analysis is also made for each test. Experimental data and analytical predictions are found to be in good agreement.

78-1814

Torsional Oscillations of an Infinite Cylindrical Elastic Tube Under Large Internal and External Pressure

H. Engin and E.S. Suhubi Tech. Univ. of Istanbul, Turkey, Intl. J. Engr. Sci., 16 (6), pp 387-396 (1978) 1 fig, 2 tables, 10 refs

Key Words: Tubes, Elastomers, Torsional vibration

This study is concerned with the small amplitude torsional oscillations of a hyperelastic infinite circular cylindrical thick tube made of a rubber-like material subjected to a large static internal and external pressure. The material is represented by a Mooney-type strain energy relation. The governing differential equation is first solved by the Frobenius method, then a variational approach, which is more suitable for numerical calculations, is developed. Several values for the natural frequencies are obtained.

78-1815

Cure Exchanger Acoustic Vibration

E.A. Barrington

Shell Oil Co., Houston, TX, Hydrocarbon Processing, 57 (7), pp 193-200 (July 1978) 10 figs, 2 tables, 9 refs

Key Words: Heat exchangers, Tubes, Acoustic resonance

Shell side acoustic vibrations can occur in tubular exchangers. Flow phenomena can generate unacceptably loud noise and potentially destructive pressure fluctuations due to the acoustic characteristics of the tubular heat exchanger. Such effects have been particularly noted in exchangers with natural gas, hydrogen-rich vapor, nitrogen gas or flue gas on the shell side. Trends in current design towards larger diameter tubulars and higher fluid velocities increase the likelihood of severe problems due to acoustic resonance. The occurrence of acoustic resonance is predicted and it is shown how to avoid the problem by proper design features.

PLATES AND SHELLS

(Also see Nos. 1707, 1731, 1788)

78-1816

Non-Linear Resonances in the Forced Responses of Plates. Part II: Asymmetric Responses of Circular Plates

S. Sridhar, D.T. Mook, and A.H. Nayfeh
Dept. of Engrg. Science and Mechanics, Virginia
Polytechnic Inst. and State Univ., Blacksburg, VA
24061, J. Sound Vib., 59 (2), pp 159-170 (July 22,
1978) 9 refs

Key Words: Circular plates, Harmonic excitation, Nonlinear response, Perturbation theory

The dynamic analogue of the von Karman equations is used to study the forced response, including asymmetric vibrations and traveling waves, of a clamped circular plate subjected to harmonic excitations when the frequency of excitation is near one of the natural frequencies. The method of multiple scales, a perturbation technique, is used to solve the non-linear governing equations. The approach presented provides a great deal of insight into the nature of the non-linear forced resonant response.

78-1817

Vibration of Circular Double-Plate Systems

A.S.J. Swamidas and V.X. Kunukkasseril
Dept. of Appl. Mechanics, Indian Inst. of Tech.,

Madras 600 036, India, J. Acoust. Soc. Amer., 63 (6), pp 1832-1840 (June 1978) 12 figs, 7 refs

Key Words: Circular plates, Composite structures, Vibration response

Vibrational characteristics of circular double-plate systems connected together by concentric, intermediate, elastic ring supports have been considered in this work. The analysis is based on the assumption that both of the plates are thin, elastic, and isotropic. Also, the plates are subjected to initial in-plane loads. The solutions are shown to be in terms of Bessel functions for the case of complete and annular (with equal in-plane loads) circular isotropic plate systems. The vibrational characteristics of the systems are illustrated by presenting numerical results for isotropic plate systems with one intermediate connection. When both the plates are identical with identical edge forces and boundary conditions, in-phase and out-of-phase vibration modes are observed.

78-1818

Acoustic Reflection from a Thick Plate with One Reinforcing Rib. Exact Integral Evaluation is Proved Superior to Integral Approximation in Analysis of Acoustic Reflections from a Timoshenko-Mindlin Plate Reinforced with One Rib

B.L. Woolley

Naval Ocean Systems Center, San Diego, CA, Rept. No. NOSC/TR-176, 198 pp (Dec 1977) AD-A054 610/1GA

Key Words: Plates, Acoustic reflection, Timoshenko theory, Mindlin theory, Computer programs

The reflection of a plane sound wave from a thick, i.e., Timoshenko-Mindlin, fluid-loaded elastic plate reinforced with a stiffness member is investigated. The case is first solved without using integral approximation techniques. This solution gives relatively lower returns than those given by integral approximation techniques. The solution is also found by an integral approximation technique and then by an integral approximation technique taking into account leaky wave poles. The results of numerical calculations are presented and reviewed. Computer programs are given to carry out the calculations.

78-1819

Vibration Statistics of Thin Plates with Complex Form

A. Waberski

Silesian Technical Univ., Gliwice, Poland, AIAA J., 16 (8), pp 788-794 (Aug 1978) 10 figs, 20 refs

Key Words: Probability theory, Plates

A new mathematical method of calculation of the probabilistic characteristics of mechanical systems with complex geometry is presented. This method has been demonstrated on the example of random vibrating plates. This method is based on the application of certain special functions called R functions. In order to demonstrate this method, numerical calculations are presented of probabilistic characteristics for plates with complex geometry which have been clamped on the edge.

78-1820

A General Model for the Calculation of Thick Plates (And Rods)

G. Kumbetlian

Marine Institute, Constanta, Rumania, Rev. Roumaine Sci. Tech. - Mec. Appl., 23 (2), pp 249-262 (Mar/Apr 1978) 4 refs

Key Words: Plates, Rods, Harmonic excitation

This paper presents a general theoretical model for the calculation of thick plates (and rods) under biharmonic loads, which satisfies the large majority of loads occurring in practice.

78-1821

Design of Clamped Composite-Material Plates to Maximize Fundamental Frequency

C.W. Bert

School of Aerospace, Mech. and Nuclear Engrg., Univ. of Oklahoma, Norman, OK, J. Mech. Des., Trans. ASME, 100 (2), pp 274-278 (Apr 1978) 1 fig, 6 tables, 23 refs

Key Words: Rectangular plates, Composite materials, Fundamental frequency, Optimum design, Optimization

Methodology and equations are developed for maximizing the fundamental frequency (ω _f) of small-amplitude, free flexural vibration of a clamped, rectangular plate consisting of multiple, equal-thickness layers of the same unidirectional filamentary composite material. The synthesis is based on a concise, explicit equation for ω _f in terms of plate dimensions, density, and the anisotropic flexural and torsional rigidities. The equation is developed in the paper and shown to be quite accurate.

78-1822

Buckling and Vibration of In-Plane Loaded Plates

Treated by a Unified Ritz Approach

S.F. Bassily

Teledyne Systems Co., Northridge, CA., J. Sound Vib., <u>59</u> (1), pp 1-14 (July 8, 1978) 7 figs, 2 tables, 6 refs

Key Words: Rectangular plates, Flexural vibration, Buckling, Ritz method

The problem of the buckling and lateral vibration of rectangular plates subject to in-plane loads is treated by using a Ritz approach for both the determination of the middle surface stresses caused by the in-plane loading and the analysis of the consequent out-of-plane buckling and vibrational characteristics of the plates. Since the stress function formulation of the middle surface stress problem is formally analogous to the plate bending problem, the same type of admissible functions - ordinary and degenerated beam vibration mode shapes -- are employed in the Ritz series for both parts of the problem. The approach permits the accurate treatment of plates subject to real in-plane loads, where the middle surface stresses may not be realistically representable by simple polynomials as has been assumed in earlier studies. Several numerical examples are presented, illustrating the applicability of the approach and giving an indication of the order of errors that may result in the determination of the out-of-plane characteristics of plates when using simplifying assumptions for the in-plane stress field.

78-1823

Vibration of the Elastic Cylindrical Shells (Zur Schwingung des elastischen Hohlzylinders)

U. Gamer

I. Institut f. Mechanik der Technischen Universität Wien, Vienna, Austria, Rev. Roumaine Sci. Tech. - Mec. Appl., 23 (1), pp 53-60 (Jan/Feb 1978) 2 tables, 15 refs (In German)

Key Words: Tubes, Cylindrical shells, Vibration response, Amplitude

The cylindrically symmetric vibration of an incompressible elastic tube is investigated. A phase curve is derived by means of the law of conservation of energy. Potential energy is calculated for two types of materials: the Mooney material and the modified Mooney material. A phase diagram is presented for a vibration of Mooney material. Then the dependence of vibration duration on the amplitude is investigated.

78-1824

Torsional Vibrations of Pretwisted Cantilever Plates

K. Gupta and J.S. Rao Indian Inst. of Tech., New Delhi, India, J. Mech. Des., Trans. ASME, 100 (3), pp 528-534 (July 1978) 7 figs, 6 tables, 12 refs

Key Words: Shells, Plates, Cantilever plates, Torsional vibration

A pretwisted cantilever plate is treated as a thin shallow shell. Its potential and kinetic energies in torsional vibration are determined by assuming an appropriate displacement field. Applying Hamilton's principle, the problem is reduced to a fourth-order ordinary differential equation with constant coefficients, which is solved to obtain the first four torsional frequencies of vibration. Plates of aspect ratios varying from 1.0 to 8.0 are analyzed with pretwist angles varying from 0 to 90 deg. Results of the present analysis are compared with existing theoretical and experimental results.

78-1825

Dynamics of Shells of Revolution Under Axisymmetric Load Involving Shear Deformation

Y. Tene and I. Sheinman

Faculty of Civil Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, Computers Struc., 8 (5), pp 563-568 (May 1978) 11 figs, 7 refs

Key Words: Shells of revolution, Transverse shear deformation effects, Rotatory inertia effects, Finite difference theory

A general solution procedure, based on the linear theory, is presented for arbitrary shells of revolution subjected to arbitrary axisymmetric dynamic loads. The equations of motion admit shear deformation and rotational inertia. The numerical solution is obtained by Houbolt's method and by finite differences.

78-1826

Vibration and Buckling of Fluid-Filled Cylindrical Shells Under Torsion

J. Tani and H. Doki

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, Nucl. Engr. Des., 48 (2/3), pp 359-365 (Aug 1978) 5 figs, 12 refs

Key Words: Cylindrical shells, Fluid-filled containers, Torsional excitation, Free vibration

On the basis of the Donnell-type equations modified with the transverse inertia force, the free vibration and the buckling of fluid-filled circular cylindrical shells under torsion are theoretically analyzed by using Galerkin's method. The fluid is assumed to be incompressible, irrotational and inviscid. Calculations are carried out for a simply-supported typical shell. It is found that the natural frequency of the shell under torsion decreases rapidly with the internal fluid, but the buckling load of the fluid-filled shell agrees precisely with that of the empty one.

78-1827

Studies on the Failure of Stiffened Cylindrical Shells Subjected to Dynamic Loads

C.A. Ross, R.L. Sierakowski, I.K. Ebcioglu, C.C. Schauble, and C.F. Yen

Graduate Engrg. Center., Florida Univ., Eglin AFB, FL, Rept. No. AFOSR-TR-78-0697, 249 pp (Dec 31, 1977)

AD-A053 954/4GA

Key Words: Cylindrical shells, Stiffened shells, Blast effects, Energy methods

The major objective of this study was to investigate the effects of axial stiffening of cylindrical shells subject to transverse blast loadings. Two existing methods for predicting dynamic response of cylindrical shells were modified to include axial stiffening. A semi-analytical energy method was chosen as a first cut design predictor and tables of normalized deflection versus external energy imparted to the structure are presented. In addition a more detailed analytical energy method was modified to include axial stiffening. In both cases the stiffeners were introduced by simply adding terms to the kinetic and potential energy terms of the basic shell equations rather than introducing membrane-bending coupling by use of more complicated anisotropic constitutive relations.

STRUCTURAL

78-1828

Travelling-Wave-Induced Instability of Structures

M. Farshad and I. Tadjbakhsh

School of Engrg., Pahlavi Univ., Shiraz, Iran, J. Franklin Inst., $\underline{305}$ (6), pp 343-350 (1978) 2 figs, 11 refs

Key Words: Seismic excitation, Ground motion, Structural members, Dynamic stability

The effect of transmission time of propagating disturbances on the dynamic instability of structures is discussed in this paper. Through a parametric study it is shown that for certain values of transmission time and wave frequency parameters, the structure may become dynamically unstable. An example is worked out, and graphical results depicting

the regions of instability are presented.

78-1829

Transient Response of Continuous Viscoelastic Structural Members

W.D. Pilkey and J.S. Strenkowski

Dept. of Mech. and Aerospace Engrg., Virginia Univ., Charlottesville, VA., Rept. No. UVA/525303/MAE-78/102, 33 pp (Mar 1978)

AD-A054 255/5GA

Key Words: Structural members, Viscoelastic media, Modal analysis, Beams, Plates

A comprehensive theory for the dynamic response of linear continuous viscoelastic structural members if formulated with a modal analysis. The constitutive relation is in the form of a hereditary integral. A general set of formulas is derived that may be used for both non-self-adjoint and self-adjoint systems of governing equations of motion. Applications include a Voigt-Kelvin beam and a viscoelastic circular plate.

78-1830

Transient Analysis of Structural Members by the CSDT Riccati Transfer Matrix Method

W.D. Pilkey and F.H. Chu

Dept. of Mech. and Aerospace Engrg., Virginia Univ., Charlottesville, VA., Rept. No. UVA/525-303/MAE78/103, 38 pp (Mar 1978) AD-A054 256/3GA

Key Words: Structural members, Numerical analysis, Transient response, Transfer matrix method, Bars, Beams

A method for direct integration of the dynamic governing partial differential equations of motion for structural members is presented. This technique is called the continuous space discrete time (CSDT) Riccati transfer matrix method. Numerical results for bar and beam example problems indicate that the method is numerically stable and accurate for calculating the dynamic response of linear structural members.

78-1831

Optimum Design of Bridge Girders for Electric Overhead Traveling Cranes

S.S. Rao

Dept. of Mech. Engrg., Indian Inst. of Tech., Kanpur-16, India., J. Engr. Indus., Trans. ASME, 100 (3), pp 375-382 (Aug 1978) 4 figs, 5 tables, 18 refs

Key Words: Girders, Overhead cranes, Shock absorption, Design techniques

The problem of the design of box-type bridge girders for electric overhead traveling cranes is formulated as a minimum weight design problem with inequality constraints. The restrictions placed on the design problem include limitations on the maximum allowable deflections and stresses as well as on the shock absorbing capacity during accidental collision. The overall stability and rigidity considerations are also taken into account. Several load conditons, as per the code specifications, are considered in the design problem. The resulting nonlinear programming problem is solved by using an interior penalty function method. Numerical examples are given to illustrate the effectiveness of the approach. The resulting computer program is used to make a sensitivity analysis of the problem.

78-1832

How to Design Walls for Desired STC Ratings

R.E. Jones

Forest Products Lab., Forest Service, U.S. Dept. of Agriculture, S/V, Sound Vib., 12 (8), pp 14-17 (Aug 1978) 4 figs, 1 table, 2 refs

Key Words: Walls, Noise barriers, Sound transmission loss

Sound Transmission Class STC values typical of several common wall systems are presented to illustrate a range of STC performance from about 35 to 65. The effectiveness of single-panel and double-panel designs is contrasted and a technique for calculating the transmission loss below the coincidence frequency is summarized.

78-1833

Effect of Sound-Absorptive Facings on Partition Airborne-Sound Transmission Loss

S.M. Brown, J. Niedzielski, and G.R. Spalding Res. and Dev. Center, Armstrong Cork Co., Lancaster, PA 17604, J. Acoust. Soc. Amer., 63 (6), pp 1851-1856 (June 1978) 5 figs, 2 tables, 12 refs

Key Words: Sound transmission loss, Walls, Coatings

Laboratory measurements of the improvement of partition airborne-sound transmission loss in the presence of sound-absorptive partition facings are presented. For a double-leaf partition of 1/2-in.-thick gypsum board on 2 X 4-in. studs, the application of such facings has led to improve-

ments in transmission loss in excess of 10 dB in the 1/3octave bands above 1 kHz. Corresponding, but smaller, improvements have been measured at lower frequencies.

78-1834

The Riccati Transfer Matrix Method

G.C. Horner and W.D. Pilkey Mechanical Technology Inc., Latham, NY, J. Mech. Des., Trans. ASME, <u>100</u> (2), pp 297-302 (Apr 1978) 1 fig, 4 tables, 18 refs

Key Words: Transfer matrix method, Structural members, Shafts, Rotors

The Riccati transfer matrix method is a new technique for analyzing structural members. This new technique makes use of an existing large catalog of transfer matrices for various structural members such as rotating shafts. The numerical instability encountered when calculating high resonant frequencies, static response of a flexible member on a stiff foundation, or the response of a long member by the transfer matrix method is eliminated by the Riccati transfer matrix method. The computational time and storage requirements of the Riccati transfer matrix method are about half the values for the transfer matrix method. A rotating shaft analysis demonstrates the numerical accuracy of the method.

TIRES

78-1835

P.M. Harper, Sr.

Improved Tire/Wheel Concept

Langley Res. Center, NASA, Langley Station, VA., Rept. No. N78-22374/0, NASA-CASE-LAR-11695-1, 12 pp (Apr 6, 1978) Sponsored by NASA PAT-APPL-SN-893 865/GA

Key Words: Aircraft tires, Vehicle wheels, Wheels

A tire and wheel assembly is described in which a low profile pneumatic tire has sidewalls which deflect inwardly under load and a wheel has a rim featuring a narrow central channel and extended rim flanges from the combination. The extended rim flanges support the tire sidewalls under static and dynamic loading conditions to produce a combination particularly suited to aircraft applications.

SYSTEMS

ABSORBER

78-1836

Alternative Tuned Absorbers for Steady State Vibration Control of Tall Structures

R.L. Jenniges and D.A. Frohrib
Dept. of Mech. Engrg., The Design Center, Univ.
of Minnesota, Minneapolis, MN, J. Mech. Des., Trans.
ASME, 100 (2), pp 279-285 (Apr 1978) 13 figs,
6 refs

Key Words: Tuned dampers, Vibration absorbers (equipment), Multistory buildings, Periodic response, Flexural vibration, Torsional vibration

Two forms of damped vibration absorbers are evaluated to describe their value in reducing steady state vibration of tall buildings. The first model contains a set of two identical one-degree-of-freedom elements symmetrically mounted in a horizontal plane on either side of the building's long axis. An alternate model has independent translational and torsional elements mounted at the building's center. Damping parameters are included for building funamental bending and torsion modes to evaluate those effects on response. The sensitivity of absorber performance to absorber-building mass ratio μ is of interest to minimize the size of the absorber. Performance of the absorber models was compared based on maximum transmissibility and a quality integral, which is an integrated transmissibility over a frequency spectrum based on amplification at a point on the building top.

78-1837

Response Spectra Design Methods for Tuned Equipment-Structure Systems

J.M. Kelly and J.L. Sackman
Dept. of Civil Engrg., Univ. of California, Berkeley,
CA 94720, J. Sound Vib., <u>59</u> (2), pp 171-179 (July
22, 1978) 2 figs, 8 refs
Sponsored by the Defense Nuclear Agency

Key Words: Equipment response, Equipment mounts, Tuned damping, Response spectra, Design techniques

A description is given of a design method that allows response spectra to be used to estimate maximum displacements and accelerations in equipment-structure systems. The type of system considered involves light equipment tuned to a natural frequency of the structure. The solution is developed by using transform methods, residue theory and asymptotic analysis. A very simple result is obtained which should be of value to designers of equipment, equipment mountings and non-structural components in structures subject to dynamic loading. The simple nature of the result is explained by a direct physical interpretation of the response.

78-1838

The Steady State Response of Systems with Hardening Hysteresis

R.K. Miller

Dept. of Mech. and Environmental Engrg., Univ. of California, Santa Barbara, CA., J. Mech. Des., Trans. ASME, 100 (1), pp 193-198 (Jan 1978) 6 figs, 9 refs

Key Words: Periodic response, Hysteretic damping, Viscous damping, Single degree of freedom systems, Multi degree of freedom systems

A physical model for hardening hysteresis is presented. An approximate analytical technique is used to determine the steady-state response of a single-degree-of-freedom system and a multi-degree-of-freedom system incorporating this model. Certain critical model parameters which determine the general nature of the responses are identified.

78-1839

Analysis of Performance of Pneumatic Impact Absorbers

M.S. Hundal

Dept. of Mech. Engrg., Univ. of Vermont, Burlington, VT, J. Mech. Des., Trans. ASME, 100 (2), pp 236-241 (Apr 1978) 4 figs, 7 tables, 5 refs

Key Words: Absorbers, Pneumatic dampers

Performance of impact absorbers employing a pneumatic damper and a linear spring in parallel is analyzed. The governing nonlinear differential equations are derived and converted to nondimensional form. For the case of a damper with fixed area orifice the equations are numerically integrated. Performance charts are presented in terms of three dimensionless parameters: mass, spring stiffness and orifice area ratio. Then, a second case is considered in which the damper orifice area is made to vary in two stages.

NOISE REDUCTION

(Also see Nos. 1862, 1869, 1872)

Noise Control for Fan and Vent Shafts in Subways

Wilson, Ihrig & Associates, Inc., 5605 Ocean View Dr., Oakland, CA 94618, Noise Control Engr., 10 (3), pp 102-107 (May/June 1978) 8 figs, 3 tables, 4 refs

Key Words: Fans, Subway cars, Noise control

Subway fan and vent shafts can be prominent sources of noise impact to both the adjacent community and to patrons in the subway stations. The author discusses the available methods for reduction of fan and train noise propagated out of vent shafts and fan noise propagated into stations. In addition, the results of fan noise measurements in station platforms and outside the fan shafts at existing rapid transit facilities are presented.

78-1841

Low Noise Propulsion System for General Aviation B Berdrow

Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen, West Germany, Rept. No. BMFT-FB-W-77-23, 384 pp (Dec 1977)

(In German) N78-22108

Key Words: Propulsion systems, Noise reduction, Aircraft noise

The program described is aimed at the development of low noise propulsion systems of up to 200 HP for general aviation. The study is broken down into three stages (definition, production and testing). The objective of the program is a noise reduction of 10 dB(A) in comparison to the 1975 LBA noise economy, derived from standard passenger car engines. A comprehensive noise study on possible propellers (including shrouded propellers) forms the basis for the propeller rpm's required for low noise propulsion systems. The conversion of the high rpm's normal for passenger car engines to the low propeller rpm's required is via gearboxes, which are a fundamental problem dealt with. The solution to the problem is given in the definition stage. Studies on the installation of propulsion systems in existing airframes does not show particular problems.

78-1842

The Nine Tools of Noise Control

W. Fearon

Peabody Noise Control Inc., Dublin, OH, Des. News, 34 (2), pp 26-35 (June 19, 1978) 9 figs

Key Words: Noise reduction, Design techniques, Materials

The nine avenues open to the designer to make a product quiet, grouped into two major categories – designed-in solutions and added-on solutions, are discussed. Selection of materials for barriers, absorbers, dampers and vibration isolators is discussed.

78-1843

Diffraction of Arbitrarily Oriented Directional Sources by Rigid Planar Screens

G.W. Johnston

Inst. of Aerospace Studies, Univ. of Toronto, Downsview, Ontario, Canada M3H 5T6, J. Acoust. Soc. Amer., 64 (2), pp 665-676 (Aug 1978) 11 figs, 7 refs

Key Words: Noise barriers, Guardrails

An analysis has been carried out to determine the diffracted fields due to directional sources located near rigid planar screens with application to the suppression of noise by acoustic barriers, especially highway barriers. Firstly, the diffracted field due to an arbitrarily oriented point dipole source is obtained by source position differentiation using the classical exact results due to McDonald. The dipole results are then combined with the monopole results to obtain the diffracted fields due to a series of combined sources having arbitrary directivity and orientation with respect to the plane of the screen. It is noted that while the diffraction problem with simple sources and planar screens exhibits reciprocity, diffraction results obtained in the present problem do not exhibit reciprocity with respect to source and observer locations. Typical computed insertion loss results are shown indicating the trends associated with source directionality, source orientation, and source location.

AIRCRAFT

(Also see Nos. 1725, 1726)

78-1844

Modal Investigation of Lightweight Aircraft Structures Using Digital Techniques

R.W. Gordon, H.F. Wolfe, and R.D. Talmadge Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Rept. No. AFFDL-TR-77-124, 66 pp (Dec 1977)

AD-A053 782/9GA

Key Words: Aircraft, Testing techniques, Natural frequencies, Mode shapes, Modal damping, Honeycomb structures

Digital impact response test techniques were used to measure the dynamic properties of lightweight aircraft structures to include natural frequencies, mode shapes and modal damping. Two different types of structures were tested, honeycomb and skin-stiffened panels. The digital impact response method used consisted of applying a transient force pulse to the structure, measuring the structure's response at various points, digitizing, calculating the transfer functions using fast Fourier transforms, and determining the dynamic properties from these data. A second method was used on these same structures for direct comparison purposes. This method was an analog technique using sine sweep tests and accelerometer mapping.

78-1845

Effects of Cavity Resonances on Sound Transmission into a Thin Cylindrical Shell

L.R. Koval

Dept. of Mech. and Aerospace Engrg., Univ. of Missouri-Rolla, Rolla, MO 65401, J. Sound Vib., 59 (1), pp 23-33 (July 8, 1978) 4 figs, 7 refs Sponsored by NASA

Key Words: Aircraft noise, Internal noise, Noise reduction, Cylindrical shells, Cavity resonance, Mathematical models

In the context of the transmission of airborne noise into an aircraft fuselage, a mathematical model is presented for the effects of internal cavity resonances on sound transmission into a thin cylindrical shell. The "noise reduction" of the cylinder is defined and computed, with and without including the effects of internal cavity resonances. As would be expected, the noise reduction in the absence of cavity resonances follows the same qualitative pattern as does transmission loss.

78-1846

An Acoustic Range for the Measurement of the Noise Signature of Aircraft During Flyby Operations

D.A. Hilton and H.R. Henderson Langley Res. Center, NASA, Hampton, VA 23665, Noise Control Engr., 10 (3), pp 120-126 (May/June 1978) 15 figs, 6 refs

Key Words: Aircraft noise, Acoustic signatures, Measurement techniques

The authors present a detailed description of the Remotely Operated Multiple Array Acoustic Range currently operated by NASA. Also given are examples of actual measurements that demonstrate ROMAAR's application to ground noise footprint measurement for different types of aircraft.

78-1847

Noise Prediction Technology for CTOL Aircraft J.P. Raney

Langley Res. Center, NASA, Langley Station, VA., Rept. No. NASA-TM-78700, L-12234, 16 pp (May 1978)
N78-23875

Key Words: Aircraft noise, Noise prediction, Propulsion systems

The application of a new aircraft noise prediction program to CTOL noise prediction is outlined. Noise prediction is based on semiempirical methods for each of the propulsive system noise sources, such as the fan, the combustor, the turbine, and jet mixing, with noise-critical parameter values derived from the thermodynamic cycle of the engine. Comparisons of measured and predicted noise levels for existing CTOL aircraft indicate an acceptable level of accuracy.

78-1848

Noise From Engine Thrust Reversal of Landing Aircraft

R.F. Higginson and A.J. Rennie National Physical Lab., Teddington, UK, Rept. No. NPL-Ac-83, 63 pp (Aug 1977) N78-23098

Key Words: Aircraft noise, Engine noise, Noise measurement

Measurements were made of aircraft noise, with particular reference to the levels of engine thrust reversal noise of different aircraft types at and near to London Airport - Gatwick. The object was to determine the contribution of reverse thrust noise to the total noise exposure at points on the ground. The results show that generally this contribution is small in relation to that of the principal sources of noise, aircraft taking off and climbing out.

78-1849

Community Noise Exposure Resulting from Aircraft Operations. Volume 1. Acoustic Data on Military Aircraft

J.D. Speakman, R.G. Powell, and J.N. Cole Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-1, 51 pp (Nov 1977) AD-A053 699/5GA

Key Words: Aircraft noise, Noise measurement

This report is one of a series describing the research program undertaken by the Aerospace Medical Research Laboratory to develop the procedures (NOISEMAP) and data base (NOISEFILE) for predicting community noise exposure resulting from military aircraft operations. It presents the results of field test measurements to define the single event noise produced on the ground by military fixed wing aircraft during controlled level flyovers and ground runups.

78-1850

Community Noise Exposure Resulting from Aircraft Operations. Volume 2. Acoustic Data on Military Aircraft: Air Force Bomber/Cargo Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee Aerospace Medical Res. Lab., Wright-Patterson AFB, OH., Rept. No. AMRL-TR-73-110-VOL-2, 768 pp (Nov 1977) AD-A053 700/1GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the single event noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 F temperature and 70% relative humidity. Noise data are presented in this Volume 2 for many military aircraft.

78-1851

Community Noise Exposure Resulting from Aircraft Operations. Volume 3. Acoustic Data on Military Aircraft: Air Force Attack/Fighter Aircraft J.D. Speakman, R.G. Powell, and R.A. Lee Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-3, 763 pp (Feb 1978)
AD-A053 701/9GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to

standard acoustic reference conditions of 59 deg. F temperature and 70% relative humidity. Noise data are presented in this Volume 3 for many military aircraft.

78-1852

Community Noise Exposure Resulting from Aircraft Operations. Volume 4. Acoustic Data on Air Force Trainer/Fighter Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-4, 644 pp (Feb 1978) AD-A053 702/7GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 deg. F temperature and 70% relative humidity. Noise data are presented in this Volume 4 for many military aircraft.

78-1853

Long-Distance Focusing of Concorde Sonic Boom
L. Liszka

Kiruna Geophysical Inst., S-981 01 Kiruna 1, Sweden, J. Acoust. Soc. Amer., <u>64</u> (2), pp 631-635 (Aug 1978) 9 figs, 9 refs

Key Words: Aircraft noise, Sonic boom

Infra-acoustic signals from supersonic flights of Concorde are regularly recorded in northern Sweden at distances up to 5000 km from the aircraft. Relatively high signal amplitudes (up to 0.1 $\mbox{N/m}^2)$ are explained by a kind of long-distance focusing effect. Principle and consequences of the focusing effect are discussed.

78-1854

Full Scale Crash Test Experimental Verification of a Method of Analysis for General Aviation Structural Crashworthiness

G. Wittlin, M.A. Gamon, and W.L. LaBarge Lockheed-California Co., Burbank, CA., Rept. No. LR-28306, FAA-RD-77-188, 424 pp (Feb 1978) AD-A054 154/0GA

'Key Words: Crash research (aircraft)

The results of the Task II effort to experimentally verify a method of analysis of the structural dynamics response of general aviation airplanes subjected to a crash environment are presented. Included in this report is a description of the preparation for the performance of four instrumented full-scale crash tests involving a single-engine, high wing type airplane. All crash testing was performed at the NASA Langley Impact Dynamics Research Facility (IDRF). The crash tests involved a wide range of impact attitudes and included one impact into a soil covered terrain.

78-1855

Tests of Crash-Resistant Fuel System for General Aviation Aircraft

W.M. Perrella, Jr.

Experimental Center, National Aviation Facilities, Atlantic City, NJ, Rept. No. FAA-NA-77-48, FAA/RD-78-28, 32 pp (Mar 1978) AD-A054 141/7GA

Key Words: Crash research (aircraft), Fuel tanks

A significant percentage of general aviation aircraft accidents result in postcrash fires due to the ignition of fuel spillage, often contributing injury or death to the aircraft occupants. Testing was performed to demonstrate the performance of light-weight, flexible, crash-resistant fuel cells combined with the use of frangible fuel line couplings. Included in these tests were three full-scale crash tests of a typical light twin aircraft.

BUILDING

(Also see Nos. 1717, 1744, 1745, 1746, 1747)

78-1856

Development of an Empirical Relationship for the Prediction of Damping in Steel-Framed Buildings

T.J. Rusnak

Army Military Personnel Center, Alexandria, VA, 219 pp (May 3, 1978) AD-A054 438/7GA

Key Words: Buildings, Damping, Prediction techniques

Test data from the forced vibration and ambient experiments on actual structures are used as input to a regression analysis

routine to develop equations for the prediction of damping in steel-framed buildings. The data is categorized by building height and building width (the dimension in the direction parallel to the applied forces). The best resulting equation is used as the basis for a new design methodology to predict damping. This methodology consists of using the prediction equation in a situation where a set of conditions are satisfied. These conditions pertain to the particular characteristics of the structure and the approximate level of excitation which is expected. It is anticipated that this methodology will be especially useful in the early stages of design. Included also are two types of sensitivity analysis which indicate the amount of variation in displacement response that can be expected by using the developed prediction equation.

78-1857

Inelastic Response of Multistory Buildings to Tornadoes

M. Seniwongse

Ph.D. Thesis, Texas Tech Univ., 400 pp (1977) UM 7810851

Key Words: Multistory buildings, Wind-induced excitation

The purpose of this research project is to perform a computer study of the response of multistory steel frame buildings to tornadic winds in order to determine if such structures can be economically designed to withstand tornadoes and, if so, what design provisions would be appropriate. A number of factors and their effects on the building response are investigated. These factors include various parameters describing the tornado windfield, the effects of dynamic as well as static response, and the influence of yielding, non-structural stiffness and strength, and ${\bf P}=\Delta$ moments.

78-1858

Earthquake Simulation Tests of a Nine Story Steel Frame with Columns Allowed to Uplift

A.A. Huckelbridge

Ph.D. Thesis, Univ. of California, Berkeley, 177 pp (1977)

UM 7812455

Key Words: Buildings, Seismic response, Computerized simulation, Experimental data

This thesis presents experimental and analytical response data for a model nine-story building frame under seismic excitation, both with and without supplementary anchorage of the columns provided. The experimental work was carried out on the shaking table of the U.C. Berkeley Earthquake Simulator Laboratory.

CONSTRUCTION

78-1859

Road Construction Noise Prediction and Measurement -- A Case Study

D.M. Martin and A.V. Solaini Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL-LR-758, 28 pp (1977) PB-280 508/3GA

Key Words: Noise prediction, Noise measurement, Construction equipment, Earth handling equipment

Noise predictions and measurements have been made during the earthworks phase of a road construction scheme in order to illustrate the roles that noise prediction and measurement can play is assessing noise control strategies in earthworks operations. Measurements were made over periods of six hours or more.

FOUNDATIONS AND EARTH

(See Nos. 1749, 1837)

HUMAN

78-1860

Measurement of the Energy Dissipated in the Hand and Arm Whilst Using Vibratory Tools

J.S. Anderson and R.A.C. Boughtflower Dept. of Mech. Engrg., The City Univ., London EC1V4PB, UK, Appl. Acoust., 11 (3), pp 219-224 (July 1978) 3 figs, 6 refs

Key Words: Tools, Vibratory tools, Human response

Acceleration levels during hand-held grinding have been measured. By controlling the input to a vibration shaker the same acceleration levels were introduced into a specially designed handle gripped by a human hand. From measurements of force, acceleration and phase the power dissipated in the hand was calculated in third-octave bands. Approximate agreement was achieved with power dissipation estimates obtained form the acceleration alone by assuming the hand-arm system to be a linear, single degree of freedom system. The power dissipated is proposed as an important parameter affecting vibration-induced white finger.

78-1861

Vibration Aspects of Ride Quality Modeling for the DOT PTACV - Theory and Experiment

R. Katz

Metrex Div., MITRE Corp., McLean, VA., Rept. No. FRA/ORD-78/02, 59 pp (Dec 1977)
PB-279 846/0GA

Key Words: Ground effect machines, Ride dynamics, Human response

An important aspect of passenger ride comfort in a transportation vehicle is the acceleration level of the passenger cabin. In order to incorporate ride quality into the design process of such vehicles, it is necessary to have reasonably validated analytical models to predict the acceleration levels at frequencies which affect passenger ride comfort. The purpose of the report is to discuss the suitability of analytical models used to predict the heave acceleration in the passenger cabin of The Department of Transportation's Prototype Tracked Air Cushion Vehicle (PTACV). The basis of this evaluation is a comparison of theoretical predictions from an analytical model, typical of those in common usage today, with measured responses accumulated during testing of the PTACV on its test track.

ISOLATION

78-1862

One Stage and Two Stage Vibration Isolators as Applied to High Speed Textile Spindles to Achieve Noise Reduction

L.W. Foster

Lord Kinematics, Erie, PA, J. Mech. Des., Trans. ASME <u>100</u> (1), pp 33-40 (Jan 1978) 11 figs, 7 refs

Key Words: Textile spindles, Vibration isolators, Noise reduction

This paper describes the use of two types of elastomeric vibration isolators located between the spindle bolster and the rail to achieve reductions of vibration and noise levels associated with the spindle-bobbin-rail subsystem of spinning frames. The two types of elastomeric isolators employed are: a single-stage isolator where a bonded elastomeric mounting of annular design is placed between the bolster and the rail, and a two-stage isolator which incorporates an annular intermediate mass element between two annular elastomeric sections that provide the interfaces to the spindle and to the rail.

Optimization of Pneumatic Vibration Isolation System for Vehicle Suspension

E. Esmailzadeh

Dept. of Mech. Engrg., Massachusetts Inst. of Tech., Cambridge, MA, J. Mech. Des., Trans. ASME, 100 (3), pp 500-506 (July 1978) 13 figs, 12 refs

Key Words: Suspension systems (vehicles), Vibration isolators, Pneumatic springs, Optimization

An optimization technique is applied to evaluate the optimum values of many parameters involved for which the maximum transmitted motion to the body would be minimum over the broad frequency range. Theoretical expressions for the transmissibility of the body and the wheel, optimum values of mass ratio, stiffness ratio and damping ratio are presented. Design data are presented nondimensionally for parameter variations which are sufficiently broad to encompass a wide range of practical engineering problems.

78-1864

Optimizing Railroad Freight Car Truck Suspension Systems Having Coulomb Damping

R.L. Bullock and D.B. Cooley Standard Car Truck Co., Chicago, IL, J. Engr. Indus., Trans. ASME, 100 (3), pp 311-317 (Aug 1978) 4 figs, 4 tables

Key Words: Suspension systems (vehicles), Freight cars, Railroad cars, Coulomb friction

This paper describes the design process followed in developing a 100 ton freight car truck suspension system having coulomb damping. Classical linear vibration analysis was used for the conceptual design phase. Within the constraints placed upon truck suspension systems, a constant damping parameter, i.e., the ratio of friction force to static force imparted by the base, for all load conditions was established as a design goal. Optimization of the actual design parameters and comparison to existing truck suspensions was accomplished using the latest vehicle model developed by the AAR/TTD.

MECHANICAL

78-1865

Analytical and Experimental Studies of a Dynamic System with a Gap

S.F. Masri

Dept. of Civil Engrg., Univ. of Southern California,

Los Angeles, CA., J. Mech. Des., Trans. ASME, 100 (3), pp 480-486 (July 1978) 6 figs, 4 refs

Key Words: Forced vibration, Periodic response, Harmonic excitation, Mechanical systems, Motion-limiting stop

An analytical and experimental study is made of the forced vibration of a dynamic system with a motion-limiting stop, which is encountered in many practical cases involving mechanical equipment. An exact closed-form analytical solution is derived for the steady-state motion of the system when it is subjected to harmonic excitation. Experimental measurements with a mechanical model verify the analytical findings. The effects of various system parameters on the response are determined. Some interesting features of the motion are observed and compared to the jump resonance phenomenon exhibited by the solution of Duffing's equation.

METAL WORKING AND FORMING

78-1866

Experimental and Analytical Investigation of Self-Excited Chatter Vibrations in Metal Cutting N. Saravanja-Fabris and A.F. D'Souza

Bell Telephone Labs., Naperville, IL, J. Mech. Des., Trans. ASME, <u>100</u> (1), pp 92-99 (Jan 1978) 12 figs, 22 refs

Key Words: Metal working, Chatter, Self-excited vibrations

Chatter in metal cutting is a nonlinear self-excited vibration of the limit cycle type. This investigation is concerned with the analysis of chatter from the viewpoint of the describing function. Vibrations with different frequencies and amplitudes were superimposed on the steady feed motion of the tool in orthogonal cutting in order to simulate chatter. The relationships between the oscillating cutting and thrust forces and tool vibrations are discussed from the point of view of energy transfer and describing functions. Experimentally obtained describing functions of the dynamically varying cutting process are given. The stability of a typical machine tool structure under primary chatter conditions with dynamical cutting process represented by its describing function is discussed.

78-1867

Investigation of the Cutting Process Dynamics in Turning Operations

K. Srinivasan and C.L. Nachtigal Shell Development Co., Houston, TX, J. Engr. Indus., Trans. ASME, 100 (3), pp 323-331 (Aug 1978) 9 figs, 7 tables, 13 refs Key Words: Cutting, Chatter, Machine tools, Parameter identification technique

This paper describes the application of a sequential equation error minimization technique to determine empirically the optimum parameter values in a predetermined set of force component models from dynamic cutting data. The identification technique was verified on an analog computer simulation of the dynamic behavior of a machine tool system. The identified parameter values were compared with the actual simulated values.

78-1868

Identification of Machining System Dynamics by Equation Error Minimization

K. Srinivasan and C.L. Nachtigal Shell Development Co., Houston, TX, J. Engr. Indus., Trans. ASME, 100 (3), pp 332-339 (Aug 1978) 6 figs, 4 tables, 1 ref

Key Words: Parameter identification technique, Machine tools, Chatter, Self-excited vibration

The application of a sequential equation error minimization method to the identification of the dynamics of machining systems is described here. The development of the identification method was motivated by the need for models of machining system dynamics for the design of active chatter controllers. The dynamic cutting force parameters as well as the machine structure transfer function parameters are required for this task.

OFF-ROAD VEHICLES

78-1869 Off-Highway Hydraulic Noise

Auto. Engr., <u>86</u> (9), pp 34-40 (Sept 1978) 7 figs, 4 refs

Key Words: Off-highway vehicles, Agricultural machinery, Noise control

Sources of hydraulic noise and ways to minimize it are examined. Two specific examples of noise control are offered: one for a harvesting machine, the other for a roughterrain forklift truck used by the military.

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 1766, 1794)

78-1870

Nonlinear Resonance as the Cause of Multiple Pure Tones

P.G. Vaidya and K.S. Wang

Boeing Commercial Airplane Co., Seattle, WA, J. Aircraft, 15 (8), pp 526-533 (1978) 4 figs, 14 refs

Key Words: Fans, Ducts, Noise generation, Resonant response, Noise reduction

When the fans of aeroengine ducts go supersonic, they often produce radiation at the subharmonics of blade-passage frequency, known as multiple pure tones (MPT). It has been shown that the conventional explanation, that these MPT's are created by the shock waves, is inadequate. An alternative mechanism based on the concept of a "strong interaction" between the harmonics is proposed. Expression for the governing equation for such an interaction is derived. The results show an improved agreement with observed data. The analysis has also led to several practical suggestions for a suppression of the noise.

78-1871

Controlling Fan Noise In and Around Power Plants J.G. Funk

Environmental Elements Corp., Power, 122 (9), pp 114-117 (Sept 1978) 8 figs

Key Words: Fans, Noise reduction

A procedure for reducing the inlet, exhaust, and casing noise from forced- and induced-draft and primary-air fans is described.

78-1872

Generation and Suppression of Fan-Compressor Noise

S.L. Sarin

Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, Rept. No. FOK-3-1823, 22 pp (1977) N78-22107

Key Words: Fans, Compressors, Aircraft noise, Noise reduction, Acoustic linings

The generation mechanism of fan-compressor noise during the landing phase of an aircraft is examined. Various techniques (reduction of interaction tones at the source, flow choking, use of acoustic liners) to suppress this component of total aircraft noise are described. It is concluded that the choice of an optimum liner for the maximum possible suppression demands a predictive capability with regard

to liner optimum impedance, and its translation into a real hardware, and liner performance.

RAIL

(Also see No. 1729)

78-1873

An Investigation of Techniques for Validation of Railcar Dynamic Analyses

W.J. Fallon, N.K. Cooperrider, and E.H. Law Dept. of Mech. Engrg., Airzona State Univ., Tempe, AZ, Rept. No. FRA/ORD-78/19, 123 pp (Mar 1978) PB-279 996/3GA

Key Words: Railroad cars, Freight cars, Interaction: railwheel, Mathematical models, Spectral energy distribution techniques

A linear model of the vertical dynamics of a railcar was validated by the application of spectral techniques to experimental data. Track input spectra were computed from test track surface measurements gathered in the TDOP test program. Acceleration measurements of a freight car were used to compute vehicle acceleration spectra in response to the test track. The corresponding response of the linear model was computed from the analytical transfer functions and experimental track input spectra. Validation of the linear model was based upon a comparison of corresponding analytical and experimental vehicle acceleration spectra. The truck suspension was isolated and analyzed from experimental measurements of corresponding truck and car body accelerations. Spectral functions were employed to evaluate the assumptions of suspension linearity.

78-1874

Dynamics of a High-Speed Sliding Power Collector in Consideration of Sliding Friction

K. Yoshida and T. Shimogo

Faculty of Engrg., Keio Univ., Yokohama, Japan, J. Mech. Des., Trans. ASME, 100 (2), pp 242-250 (Apr 1978) 18 figs, 1 table, 6 refs

Key Words: High speed transportation systems, Sliding power collector, Interaction: rail-wheel, Sliding friction, Mathematical models

Considering the sliding friction force produced between a

contactor and a rigid collecting rail with a randomly wavy surface, the paper deals with the dynamics of a sliding power collector for a very-high-speed railway. An analytical model is formulated, which has two contact points and takes into account the pitching of a contactor, the stiffness of the sliding direction in a contactor support system, and the non-linearity of the contact stiffness between a contactor and a rail. Mainly, the influences of the sliding friction and the contact stiffness on the dynamic characteristics, i.e., the contact force variation, the probability of contact break, etc., are investigated.

REACTORS

78-1875

Vibration Analysis of Heat Exchanger and Steam Generator Designs

M.J. Pettigrew, Y. Sylvestre, and A.O. Campagna Chalk River Nuclear Labs., Atomic Energy of Canada, Ltd., Chalk River, Ontario KOJ IJO, Canada, Nucl. Engr. Des., 48 (1), pp 97-115 (June 1978) 20 figs, 2 tables, 25 refs

Key Words: Nuclear reactor components, Heat exchangers, Boilers, Fluid-induced excitation, Design techniques

A thorough flow-induced vibration analysis of nuclear components such as heat exchangers and steam generators is essential at the design stage to ensure good performance and reliability. This paper presents our approach and techniques in this respect.

78-1876

Engineering of Nuclear Power Facilities for Earthquake Loads

A.H. Hadjian

Los Angeles Power Div., Norwalk, Bechtel Power Corp., P.O. Box 60860 - Terminal Annex, Los Angeles, CA 90060, Nucl. Engr. Des., 48 (1), pp 21-47 (June 1978) 15 figs, 6 tables, 32 refs

Key Words: Nuclear power plants, Seismic design

The state-of-knowledge to engineer nuclear power facilities for earthquake loads is reviewed as it was collectively presented at the fourth SMiRT Conference. All aspects of the design process are critically examined starting with the definition of ground motion. Both past achievements in each of the several areas of endeavor, and the gaps in our knowledge that need further research and study are emphasized. Several alternatives to above ground facilities are reviewed, and issues are raised regarding easy solutions to very complex problems associated with these alternatives.

Seismic Response of Gas-Cooled Fast Breeder Reactor Core Structural Assembly Via Modal Synthesis T.H. Lee and A.S. Chuang

General Atomic Co., San Diego, CA 92138, Nucl. Engr. Des., <u>49</u> (3), pp 269-277 (Sept 1978) 8 figs, 17 refs

Key Words: Seismic response, Nuclear reactors, Modal synthesis

An investigation has been conducted to determine theoretically the dynamic response of the GCFR core support structural assembly when subjected to boundary excitation from seismic disturbances. The system analyzed consists of a thick grid plate to which many core elements are vertically attached. The dynamic problem was solved by synthesizing component modes of two substructures and treating them as continuous subsystems. Numerical system modal data and time-history response results are presented.

RECIPROCATING MACHINE

(Also see No. 1769)

78-1878

Influence of the Periodic Variations of the Mass Inertia on the Torsional Vibrations of a Four-Cylinder Engine (Einfluss der periodischen Schwankung des Massentragheitsmomentes auf die Torsionsschwingungen des Vierzylinder-Motors)

H. Klier

Lustheide 95, D-5060 Bergisch Gladbach 3, Germany, MTZ Motortech. Z., 39 (7/8), pp 341-345 (July/Aug 1978) 3 figs, 3 tables, 4 refs (In German)

Key Words: Engine vibration, Diesel engines, Torsional vibration, Damping

This paper describes the effect of periodic mass inertia variation of crank assembly. For this purpose, series of torsional vibration measurements were made by systematically changing the sizes of mass inertia moment at the flywheeland front end side of the crankshaft. The engine used is a small fast running four-cylinder diesel, designed for passenger cars.

78-1879

Current Alternatives in Exhaust System Acoustical Evaluation

L.J. Eriksson

Nelson Industries, Inc., Stoughton, WI, S/V, Sound Vib., $\underline{12}$ (8), pp 18-25 (Aug 1978) 17 figs, 1 table, 21 refs

Key Words: Engines, Exhaust noise

Various procedures for the evaluation of exhaust system performance are presented and discussed. Analytical as well as experimental techniques are considered. Comparisons are made with measurements on actual engine exhaust noise. The major approaches are ranked with respect to accuracy and cost.

ROAD

(Also see No. 1728)

78-1880

Important Data for Lateral Vehicle Dynamics (Wichtige Daten f. die Kurshaltung von Kraftfahrzeugen)

Institut f. Fahrzeugtechnik, Hans-Sommer-Strasse 4, 3300 Braunschweig, Automobiltech. Z., <u>80</u> (6), pp 263-270 (June 1978) 5 figs, 4 tables, 7 refs

Key Words: Automobiles, Steering effects, Lateral response

Four frequency responses concerning the driver-vehiclesystem are examined herein. Input is the steering wheel angle, outputs are yaw velocity, sideslip angle, lateral acceleration and steering wheel torque. The velocity is kept constant.

78-1881

Research Safety Vehicle - Phase II. Volume II. Comprehensive Technical Results

N. DiNapoli, M. Fitzpatrick, C. Strother, D. Struble, and R. Tanner ${\sf Tanner}$

Minicars, Inc., Goleta, CA., Rept. No. DOT-HS-803 250, 609 pp (Nov 1977)
PB-280 153/8GA

Key Words: Collision research (automotive)

Phase I identified trends leading to the desired national social goals of the mid-1980's in vehicle crashworthiness, crash avoidance, damageability, pedestrian safety, fuel economy, emissions and cost, and characterized an RSV to satisfy them. In Phase II an RSV prototype was designed, developed and tested to demonstrate the feasibility of meeting these goals simultaneously.

ROTORS

(Also see Nos. 1752, 1834)

78-1882

A Simple Stability Analysis for Flexible Rotors in Tilting Pad Bearings

E.A. Bulanowski

Solid Mechanics Res. and Advanced Product Dev., Delaval Turbine, Inc., Trenton, NJ., J. Mech. Des., Trans. ASME, 100 (1), pp 165-172 (Jan 1978) 10 figs. 1 table, 5 refs

Key Words: Rotor-bearing systems, Tilting pad bearings, Stability analysis

A simplified stability analysis for flexible rotors in tilting pad bearings is developed which provides a convenient and practical approach for the consideration of nonsynchronous vibrations during the design phase of rotor bearing systems. This paper demonstrates that the free vibrations, and hence the system damping factor, of a distributed mass flexible rotor in tilting pad bearings may be analyzed using a single mass, two tier spring-damper model. The relationship between the system damping factor and rotor stability is discussed. Nonsynchronous tilting pad bearing characteristics are incorporated into the expression for the damping factor, and nondimensional curves are presented which establish values of the damping factor as a function of operating speed, critical speed, bearing clearance and Sommerfeld number. The subject curves provide a quick method for establishing stability guidelines during rotor design and for comparing existing rotor bearing systems.

78-1883

The Stability of an Asymmetric Rotor in Damped Supports

A.J. Smalley, J.M. Tessarzik, and R.H. Badgley Mechanical Technology, Inc., Latham, NY, ASME Paper No. 78-GT-172

Key Words: Rotor-bearing systems, Tilting-pad bearing

A general-purpose method of evaluating the stability of an asymmetric flexible rotor, mounted in symmetric damped bearings, is defined. This method evaluates the complex eigenvalues of the rotor system by solving the equations of motion in a rotating coordinate frame. The application of this method to a rotor mounted in tilting-pad bearings is demonstrated. The observed behavior of a number of different rotor configurations is compared with corresponding predictions of stability.

78-1884

The Dynamics of Multi-Rotor Systems Supported on Oil Film Bearings

A.G. Holmes, C.M.M. Ettles, and I.W. Mayes Dept. of Mech. Engrg., Imperial College, London, UK, J. Mech. Des., Trans. ASME 100 (1), pp 156-164 (Jan 1978) 12 figs, 9 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Oil film bearings, Alignment, Self-excited vibrations

The self-excited transverse vibration of an elastic multirotor system due to vertical misalignment of the support bearings is investigated using initial value problem techniques. The equations of motion are expressed in terms of the free-free modes of the shaft and the modal coefficients propagated in time. The method was used to study a two-rotor four-bearing system subjected to misalignment.

78-1885

Some Experiments on Instability of Rotors Supported in Fluid-Film Bearings

J. Tonnesen and J.W. Lund

Dept. of Machine Elements, The Technical Univ. of Denmark, 2800 Lyngby, Denmark, J. Mech. Des., Trans. ASME, 100 (1), pp 147-155 (Jan 1978) 20 figs, 11 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Experimental data, Whirling, Unbalanced mass response

Experiments are conducted on two rotors supported in cylindrical bearings with two axial grooves. The journal position in the bearing is measured by built-in capacitance displacement probes, and the dynamic behavior is monitored by pressure probes. The self-excited whirl at the threshold speed of instability, as well as the influence of unbalance on the whirl frequency, is investigated in detail. By adding damping at the supports, the heavier rotor is stabilized and operated up to 330 Hz. Correlation with theoretical predictions is presented.

78-1886

Finite Element Analysis of Rotor-Bearing Systems with Matrix Reduction

K.E. Rouch

Ph.D. Thesis, Marquette Univ., 263 pp (1977) UM 7810293

Key Words: Rotor-bearing systems, Finite element technique, Computer programs

This dissertation investigates the application of the finite element technique to dynamic analysis of rotor-bearing systems. In addition, the use of reduced stiffness, mass, and damping matrices to represent the shaft, in place of the complete global stiffness matrices, is explored.

78-1887

Keep Rotor Vibration Under Control

M.L. Adams

Univ. of Akron, Akron, OH, Power, 122 (8), pp 28-29, 65 (Aug 1978) 3 figs, 5 refs

Key Words: Rotor-bearing systems, Subharmonic oscillations, Vibration damping

Rotor subharmonic resonance is a potentially catastrophic vibration phenomenon that could happen in units with fixed-arc journal bearings if a large rotor imbalance occurs, for example, as a result of a turbine blade loss. Properly designed pivoted-pad bearings, unlike fixed-arc bearings, do not lose their damping ability in the subsynchronous frequency range, thus provide effective damping of subharmonic vibration.

78-1888

Critical Speeds, Stability and Response of a Geared Train of Rotors

J.W. Lund

Dept. of Machine Elements, The Technical Univ. of Denmark, Lyngby, Denmark, J. Mech. Des., Trans. ASME, 100 (3), pp 539-535 (July 1978) 9 refs

Key Words: Rotors, Torsional vibration, Lateral vibration, Forced vibration, Free vibration

A method is described for calculating the coupled torsionallateral vibrations in a geared system of rotors. It considers both forced vibrations, caused by mesh errors or by mass unbalance, and free, damped vibrations whose complex eigenfrequencies define the damped critical speeds and the stability of the rotor system. The rotors, supported in fluidfilm bearings, are calculated independently, using the Holzer method for torsional vibrations and the Myklestad-Prohl method for lateral vibrations, after which they are coupled through impedance matching at the gear meshes. The resulting equations are solved for the unknown mesh contact forces, and the roots of the coefficient matrix determinant give the eigenvalues of the system. The method is efficient and readily programmed.

78-1889

Transient Response of a Rotor in Damped Bearings W.D. Pilkey, J.S. Strenkowski, and P.Y. Chang Univ. of Virginia, Charlottesville, VA., J. Mech. Des., Trans. ASME, 100 (2), pp 257-265 (Apr 1978) 7 figs, 10 refs

Key Words: Rotors, Transient response, Mathematical models, Modal analysis

In this paper, the transient response of a rotor subjected to a general forcing function is presented. The rotor model permits any number of in-span bearings, which include stiffness, damping, and mass properties. The excitation forces may include distributed loadings along the rotor as well as transient bearing base motion. The response is found by use of a modal analysis that incorporates the damped mode shapes. An illustrative example is presented of a rotor subjected to an initial displacement and a saw-tooth bearing base displacement.

78-1890

Residual-Flexibility Corrections for Transient Modal Rotordynamic Models

D.W. Childs and J.B. Bates, III
Speed Scientific School, Univ. of Louisville, Louisville, KY, J. Mech. Des., Trans. ASME, 100 (2), pp 251-256 (Apr 1978) 8 figs, 10 refs

Key Words: Rotors, Modal analysis, Mathematical models

An extension is presented to a modal formulation for the dynamics of flexible rotors. To date, rotordynamic modal formulations have retained for integration those modes of vibration whose natural frequencies are within or slightly above the operating speed range of the rotor, with higherorder modes simply discarded. In this study, the residualflexibility technique is employed to account for the "static" contribution of these higher-frequency modes without requiring their integration. The residual-flexibility technique accounts directly for the static contribution of higher frequency modes due to imbalance and external transient loading, and has been adapted to account for reaction forces which are not accounted for by the nominal rotor/bearing stiffness matrix, e.g., bearing damping forces or speed-dependent bearing stiffnesses. The High-Pressure-Oxygen Turbopump of the Space Shuttle Main Engine (SSME) is analyzed.

78-1891

Steady-State Unbalance Response of a Three-Disk Flexible Rotor on Flexible, Damped Supports

R.E. Cunningham

Lewis Res. Center, NASA, Cleveland, OH, J. Mech.

Des. Trans. ASME, <u>100</u> (3), pp 563-573 (July 1978) 15 figs, 15 refs

Key Words: Unbalanced mass response, Rotors (machine elements), Squeeze-film dampers

Experimental data are presented for the unbalance response of a flexible, ball bearing supported rotor to speeds above the third lateral bending critical. Values of squeeze film damping coefficients obtained from measured data are compared to theoretical values obtained from short bearing approximation over a frequency range from 5000 to 31,000 cycles/min. Experimental response for an undamped rotor is compared to that of one having oil squeeze film dampers at the bearings.

78-1892

Torsional Frequencies of Multi-Stepped Shafts with Rotors

D.K. Rao

Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur, India., Intl. J. Mech. Sci., 20 (7), pp 415-422 (1978) 4 figs, 2 tables, 12 refs

Key Words: Crankshafts, Shafts, Rotors, Inertia effects, Torsional response, Natural frequencies

An exact frequency determinant for natural frequencies of a multi-stepped shaft-rotor system, which includes the effect of shaft inertia, is developed. Frequency equations and modes of a heavy homogeneous engine, and those with one or two additional rotors, are derived using this result. Numerical results indicate that the effect of shaft inertia reduces with an increase in the mode number.

78-1893

Buckling and Vibration of a Rotating Spoke

W.D. Lakin, R. Mathon, and A. Nachman Dept. of Mathematics, Univ. of Toronto, Toronto, Canada, J. Engr. Math., 12 (3), pp 193-206 (July 1978) 4 figs, 9 refs

Key Words: Wheels, High speed rotors, Eigenvalue problems

The buckling and vibration of the spoke of a rotating wheel is examined. Since the axial load is a function of position closed form solutions for the eigenmodes are prescribed and recourse is made to regular and singular perturbation expansions in terms of several dimensionless parameters appearing in the governing equations. Some numerical results are also included in the interest of completeness.

SELF-EXCITED

(See No. 1867)

SPACECRAFT

(See Nos. 1774, 1775)

TRANSMISSIONS

(Also see No. 1804)

78-1894

Load Distribution in Timing Belts

G. Gerbert, H. Jonsson, U. Persson, and G. Stensson Machine Elements Div., Lund Tech. Univ., Lund, Sweden, J. Mech. Des., Trans. ASME, 100 (2), pp 208-215 (Apr 1978) 24 figs, 6 refs

Key Words: Belt drives, Mechanical drives

A theory is presented for determining the distribution of the belt tension and the tooth load in timing belts. It appears that the distribution of both loads is of exponential character and one important parameter is the ratio between the spring constant of the tooth and the spring constant of the cord (a nondimensional number). Friction between the belt and the top of the pulley is also considered.

TURBOMACHINERY

78-1895

An Analytic Study of the Energy Dissipation of Turbomachinery Bladed-Disk Assemblies Due to Inter-Shroud Segment Rubbing

R.L. Bielawa

Rotary Wing Technology Group, United Technologies Research Center, East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (2), pp 222-228 (Apr 1978) 9 figs, 3 refs

Key Words: Turbomachinery blades, Shrouds, Energy dissipation, Coulomb friction

A novel computational method is presented for analytically studying the energy dissipative characteristics of turbo-machinery bladed-disk assemblies due to inter-shroud segment rubbing. Coulomb friction, as the dissipative mechanism, is utilized in this method with broader generality than that in other similar studies heretofore. The immediate objectives of this study were to obtain an understanding of the

general slippage characteristics of the shroud segment interfaces in the presence of both steady normal (to the shroud segment interfaces) lock-up stresses and stresses due to modal vibration, and to incorporate these characteristics in a calculation of the minimum modal deflection required for incipient slipping as well as an estimation of the energy dissipation (damping) due to subsequent rubbing.

78-1896

Unsteady Flows in Turbomachines: A Review of Current Developments

M.F. Platzer

Naval Postgraduate School, Monterey, CA., In: AGARD Unsteady Aerodyn., 28 pp (Feb 1978) N78-22065

Key Words: Turbomachinery, Aerodynamic response, Prediction techniques

The state-of-the-art of turbomachinery unsteady aerodynamics is reviewed with emphasis on theoretical prediction techniques.

ANNUAL AUTHOR INDEX

	į –	
Α	Allemang, R.J 1074	Atkočiūnas, J
• •	Allen, D.S 1271	Attenborough, K 1541
	Allen, H.C	Auret, F.D 1060
Abbas, B.A.H 829	Almroth, B.O 706	Aurich, H 600
Abbas, S.F	Alspaugh, D.W 1253	Auslander, D 1419
Abbott, J.M349, 517	Altman, W	Au-Yang, M.K
Abdel-Ghaffar, A.M 1019	Altus, E 953	Avinor, M 1430
Abdulkarim, O.I	Alwar, R.S	Ayre, R.S
Abe, E 1085	Amari, M 1443	Azuma, T 1394
Abedi-Hayati, S 1419	Ambardar, A 1172	
Abel, I 1256	Amdursky, V	
Abel, L.W 630	Andersen, C.M 301	В
Abraham, B	Anderson, D.L	5
Abrahamson, A.L94	Anderson, G.L	Babuska, I
Abrahamson, G.R933	Anderson, J.C 665	Bachschmid, N
Abrams, C.F., Jr	Anderson, J.S 1860	Badgley, R.H
Achenbach, J.D 712	Anderson, R.J	Baig, M.I
Adams, G.H	Anderson, R.L 795, 796, 797	Bailey, C.D 1292
Adams, M.L 1887	Anderson, W.J	Bailie, J.A 706
Adams, T.P 188	Anderson, W.W 870	Bainum, P.M 1774, 1775
Adamson, A.P 826	Andersson, G.O 493	Baitis, A.E
Adeli, H 830	Ando, Y	Baker, E.W 63
Adler, A 1592	Andrej, G 1190	Baker W.E
Agarwal, G.C	Andresen, J.A 1187	Balachandra, M.B 74
Agbabian, M.S 60	Andress, E.A 1421	Baladi, G.Y614
Ahlbeck, D.R472, 1034	Andrew, L.V	Balanis, G.N 1553, 1573
Ahlers, E.B 467	Andrews, D.W 1011	Balasubramanya, H.M 1029
Ahmade, G 1141	Andrews, J.G	Ballard, R.F., Jr 1057
Aida, T	Antonides, G	Banerian, G823
Ainsworth, O.R 913	Aravamudan, K.S 1429	Banerjee, D 590
Aishton, T.H 1006	Arbabi, F 155	Banerjee, M.M 1613
Akay, A	Ardayfio, D	Banerjee, S 419
Akkas, N	Arndt, R.E.A	Bansal, P.N 1752, 1753
Alem, N.M	Arnemann, J 1727	Bapu Rao, M.N 1312
Alexander, A.M 533	Arnquist, J.L	Baranski, B.R
Alexandridis, A.A67	Arora, J.S 1705	Barber, T.J 811
Alfaro-Bou, E 793	Artobolevskii, I.I 1660	Barboni, R 1691
Alfredson, R.J	Asano, K	Barcilon, V 1776
Al-Hassani, S.T.S 980	Ash, J.E 1671	Barlett, F.R1431, 1434
Alicke, G	Ashley, H 1326, 1522	Bar Itzhack, I.Y 1061
Al-Jumaily, A.M80, 1788	Ashworth, R.P 1695	Barman, A
Al-Khattat, I.M 583	Astley, R.J 1299	Barna, P.S
Allaire, P.E 892, 1129,	Asztely, J	Baron, M.L
1193, 1512	Atalik, T.S 789	Barr, A.D.S 510, 774, 1287, 1695

Barrett, L.E 892, 1129, 1196	Berardino, J.J 683	Bollinger, J.G
Barrington, E.A 1815	Berdrow, B 1841	Boni, L 1688
Bassily, S.F 1822	Berg, J.v.d	Bonn, M.R
Basu, P.K	Berger, B.S 108, 109, 1145	Bonnett, M 1270
Bartel, C	Berglund, J.W 782	Boore, D.M 1742
Barth, E.W 903	Bergmann, E.P	Bore, C.L 447
Barton, C.K	Berkovits, A 1596	Borgese, D
Baruch, M 1061	Berman, A 24, 375	Bort, R.L 1245
Baschiere, R.J 988	Bernard, J.E	Boshenko, M 1205
Baseheart, T.M	Bernard, M.C 1563	Bossler, R.B., Jr 375
Basu, P.K 580	Berry, W	Böswirth, L99
Bates, J.B., III 1890	Bert, C.W 119, 1458, 1821	Botkin, M.E836
Batra, R.C	Bertero, V.V 390, 461, 675,	Botman, M
Batsinov, T 1457	788, 1799	Boughtflower, R.A.C 1860
Baublys, P	Berthelot, M	Bouwkamp, J.G735
Baumeister, K.J 280	Bertram, A 894	Bowes, M.A
Baxa, D.E 257	Bervig, D	Bowser, F.J
Bar-Yoseph, P	Besieris, I.M	Bowsher, J.M., 549
Baz, A 531	Bettess, P	Boxwell, D.A343, 422
Bazley, E.N 406	Betzhold, C327, 1633	Boyd, M.A
Beaman, J.J	Bezler, P 101, 1104	Boyd, W.N 1482
Bean, S.P 1049	Bickel, H.J	Bozich, J
Beards, C.F 1723	Bielak, J	Bradbury, J.N 1035
Bechert, D.W 35, 784	Bielawa, R.L 1895	Bradley, J.S 519
Beck, S.A 542	Bien, F90	Brass, J
Becker, H 408	Bies, D.A 1302	Bravin, O
Becker, J	Biggs, J.M	Breitbach, E 1327, 1479
Beckmann, HD889	Bigret, R540, 825	Brill, D.W
Beddoes, T.S 1683	Bishop, D.E	Brock, J.E
Bedi, A	Bishop, R.E.D 189, 758, 1362	Broersen, P.M.T 168
Bedore, R.L	1783	Broichhausen, K.D 352
Bekofske, K.L	Bisimis, E 18, 889	Broner, N
Belanger, P.R	Bismarck-Nasr, M.N 851	Bronstad, M.E
Beliveau, J.G	Bjorkenstam, U	Brooks, J.E 503
Belkune, R.W	Bjurvald, M	Brown, A.G
Bell, W.A	Blanchard, U.J 497	Brown, D
Belsheim, R.O 506	Blaszczyk, J	Brown, D.L
Beltzer, A	Bleich, H.H	Brown, K.W
Belytschko, T.B 1669	Bloch, H.P	Brown, S.M 1833
Benedetto, G	Blomquist, D.S	Brown, T.J
Benepe, D.B., Sr 450	Bloomer, H.E	Brownfield, H.A
Bennett, J.G	Bodlund, K 651	Bruce, J.R
Bennett, R.O	Bodner, S.R	Bruce, N.E
Bennett, S.C	Bodsworth, B	Bruchmüller, H.G 69
Bensema, W.D	Bogdanoff, J.L	Brueck, D.M
Bensinger, C.T	Boghani, A.B	Bruton, D
Benson, J.B	Bohannan, W.R 607	Bryant, R.W 1095
Benton, M 1801	Bohn, D	Bucco, D
Beranek, L.L 822	Bojadziev, G.N1178, 1210	Bucher, K.M 1408
	,,	

Budcharoentong, D. 1442 Budzynski, G. 1126 Bulanowski, E.A. 1882 Bull, M.K. 102 Bullen, R. 387 Bullock, R.L. 1864 Bullough, W.A. 1252 Buono, D.F. 1753 Burkhardt, T.H. 1008 Burros, R.H. 1368 Burroughs, C.B. 1462 Burrows, C.R. 184, 188 Bush, H.G. 1202 Bushnell, D. 926 Butler, T.A. 1693 Byham, G.H. 1683 Byrne, R. 1187	Cavin, R.K. 1687 Cawthorn, J.E. .70 Cawthorn, J.M. 217, 1484, 1558 Caywood, W.C. .740 Cendral, J.L. 1689, 1690 Ceranoglu, A.N. .1150 Cermak, G.W. 1078 Cermak, J.E. .676 Chae, Y.S. 1021 Chakrabarti, S. .739 Chamis, C.C. .647 Chanaud, R.C. .1559 Chandiramani, K.L. .1142, 1369 Chandra, J. .576 Chang, C. .1374 Chang, C. .1374 Chang, D.C. .630 Chang, H. .1560	Chonan, S. 578, 1440, 1614 Chopra, A.K. 229, 390, 791, 1585 Choudhary, S. 1134 Chow, J.H. 1523 Choy, K.C. 1193, 1512 Christiano, P.P. 739 Chrostowski, J.D. 747, 1710 Chu, F.H. 1830 Chuang, A.S. 1877 Chuang, S. 370 Chung, J.Y. 436 Chwieroth, F.S. 382 Chyu, W.J. 1687 Clapis, A. 537 Clapper, W.S. 68, 823 Clark, A.V., Jr. 1255 Clark, B.J. 1013 Clark, D.R. 142 Clark, J.A. 1280
С	Chang, K.Y 609 Chang, P.Y 1889	Clark, R
	Chang, S.H 1685	Clayton, R
Cadoff, M.A	Chang, Y.W 1672	Close, W.H 1396
Cadou, P.B 1493	Chao, KL 1464	Clough, D.P 391, 700, 1149
Cagley, J.R 1627	Charnley, T	Clough, R.W 675, 1149, 1645
Calcote, L.R	Chawla, D.R 534	Coates, G.D217, 798
Camac, M	Cheeseman, I.C 256	Cochran, J.E 190
Camp, R.T	Chen, F.H.K 1140	Cockayne, J.E 935
Campagna, A.O 1875	Chen, J.C 4,895	Cocking, B.J 524
Canevet, G 1634	Chen, M 1332	Coffey, C.G965, 1281
Cannarozzi, A.A	Chen, P	Cohen, M.J
Caprihan, A	Chen, P.J 241	Coke, C.F 453
Carbon, G	Chen, S.S 200, 201, 296, 945,	Cole, J.N
Carden, H.D	976, 1456, 1813	Collins, J.A
Cardou, A900	Chen, T.L.C	Collins, J.D 49
Carey, W.W 1714	Chen, Y	Collins, K.M 1276
Carlsoeoe, S	Chen, Y.N	Collins, R.G
Carlson, R.L 409	Chenault, D.M	Collmann, K.D
Carlton, D	Chenoweth, H.B 1480	Colpin, J
Carne, T.G	Chenoweth, J.M947	Colsher, R
Carpenter, J.E 434	Cherchas, D.B	Colton, D
Carrier, R 1361	Chesta, L 456	Commins, D.E
Carta, F.O 810	Chester, C.V 1565	Connelly, W.H
Caruso, H 1432	Cheung, Y.K 1644	Connor, W.K 1079
Casirati, M	Chi, M 1728	Cooke, R.F 573
Castellani, A 1411	Childs, D.W874, 1890	Cooley, D.B
Castoldi, A 1043	Chirby, A.E	Cooperrider, N.K 473, 1729,
Catherines, J.J 1635, 1636	Chiu, H	1873
Cattaneo, L.E 1221	Cho, A.C	Corbin, B
Caughey, T.K632, 1525	Chon, C.T	Cornell, R.W 1803

Cost, T.L 153, 1620, 1623, 1708	Davies, H.G 1734	Distefano, N 1528
Costantino, C.J 697	Davies, M	Dittmar, J.H 617, 1010, 1666
Costello, G.A	Davis, A.M.J 1386	Dittrich, G 1661
Coull, A 1643	Davis, J	Dix, R.C511
Coulter, G	Davis, L.K	Dobeck, G.J 1383
Coupry, G 1639	Davis, W.R., Jr	Dodd, V.R 539, 1109
Craggs, A	Dawson, B411, 1521	Doggett, R.V., Jr 1481
Craig, R.R., Jr 199	Dawson, T.H 1569	Dokainish, M.A 150
	Dayman, B., Jr	Dokhac, M
Cramer, P.L		
Cramer, P.L	De, S 1225, 1543, 1544, 1722	Doki, H
Crandall, S.H	de Alba, P	Dokumaci, E 1600
Crews, S.T	De Barcellos, C.S 1215	Dollyhigh, S.M449
Crighton, D.G 256, 302, 961	deBarranger, A	Done, G.T.S 911
Crimi, P 1101	DeChoudhury, P	Donnelly, H.L 740
Crist, R.A 1221	Decker, E 1727	Doran, A.L 875
Crocker, M.J 441, 718, 1081	Deel, J.C	Dorey, A.D 173
Cronin, D.L	Degener, M 772, 894, 1200	Dornfeld, D.A 1503, 1504
Cross, J.L	Delany, M.E	Dornfeld, W.H 1258
Cross, R 209	Delauzun, F.R 464	Dove, R.C
Crostack, H.A 650	DeLoach, R 863, 1484, 1558	Dowell, E.H
Crowson, R.D 61	Delph, T.J	Dowling, A 1306
Culver, C	Demiray, H 662	Dowling, P.J 845
Cummings, A	Dempsey, T.K	Downs, B
Cumpsty, N.A	Dennison, E.E 1042	Doyle, G.R., Jr 879
Cunningham, A.M., Jr 450	Densmore, J.E	Doyle, V.L
Cunningham, R.E 754, 1051,	Dent, E.J 1685	Dozier, L.B 1706
1891	Denver, R.E	Dragonette, L.R 1077
Cupp, R.E	Deo, R.B	Drake, M.L
Cupps, F.J	De Pater, , A.D	Drenick, R.F392, 1545
Curami, A 540	DerHagopian, J 569	Dresig, H
Curreri, J.R 40, 101, 1104	Derham, C.J 1404	Drevet, P
, , ,	De Rouvray, A.L 1584	Drosjack, M.J 838
	Deruntz, J.A 944	D'Souza, A.F
	DeSilva, B.M.E420, 1789	Dubey, R.N
D	Destuynder, R724	Dublin, M 1686
	Deurden, C 1537	Dubois, J.J 1584
Dagen, J.D 153	deV. Batchelor, B 1785	Dubowsky, S 1, 1805
Dahlberg, T	DeVries, W.R	Duchild, R.H
Dalal, J.S 1399, 1400	Dey, S.S	Duda, J
Dalibert, A	Dhar, M 1377	Duffek, W23
Daniels, B.E 291	Dharmarajan, S 120	Duggin, B.W
Darlow, M.S 1152, 1568, 1755	Diana, G	Duke, G.A834
Das, B.M	Dicus, J 1296, 1793	Dukkipati, R.V 1804
Das, S.C	Dietrich, D.A349, 745	Dumont, R.S 572
Dasgupta, G	Diez, L	Dunderdale, T.C
Dash, P.K	DiMaggio, F.L 236, 807, 999,	Dungar, R 1579
Dastoli, B.J 604	1000, 1542, 1624	Dunn, S.E
Datta, P.K	Dimaragonas, A.D474	Duponchel, J.P29
Dau, K	DiNapoli, N	Durenberger, D.W 721, 1011
Davidson, I	Di Pasquantonio, F622	Durgunoglu, H.T 1746
Davidson, 1 1000	51. asquartomo, 1	La gariogia, i.i. i i i i i i i i i i i i i

Dutt, D.N. 1446 Dyer, D. 1767 Dykstra, R.A. 257 Dym, C.L. 1764 Dzygadlo, Z. .730, 731	Eswaran, K. 417 Ettles, C.M.M. 1356, 1884 Evans, F.J. 1530 Evans, G.D. 404 Evensen, D.A. 747, 1710 Eversman, W. 1299, 1300 Ewins, D. 569	Firbank, T.C. 901 Firth, R.D. 1619 Fischer, E.G. 916 Fischer, K.E. 1046 Fischer, U. 504 Fish, R. 162, 1182 Fisher, D.K. 64, 65, 258 Fisher, E.A. 625
E		Fisher, W.E 594
	F	Fistedis, S.H 1672
Eastep, F.E	•	Fitzpatrick, M
Ebcioglu, I.K 1827	Estim M 1677	Fix, G.J
Eberhard, J.P	Fafian, M 1677	Flax, L
Eberhardt, W.I	Fahy, F.J 819, 1279, 1486, 1736	Fleeter, S
Edgar, L.J	Falco, M	Fleming, D.P
Edwards, J.W 857	Fallon, W.J 1873	Flis, W.J
Edwards, W.T 1357	Fancher, P.S., Jr 178	Florence, A.L
Eghbali, B 815	Fandrich, R.T	Flower, W
Egolf, D.P	Farassat, F	Floyd, J.K
Ehlers, F.E 459	Farshad, M 1612, 1828	Flynn, L
Eichler, J 1328, 1711	Fasanella, E.L 861	Foersching, H 1464
Eidinger, J.M 1404	Faulkner, L.L 80, 855, 1006,	Foley, F
Elber, W 571	1788	Foss, R.N
Eldred, P.J.L 1579	Fave, J 1578	Foster, A.W
Elishakoff, I 992	Fawcett, J.N 814, 1515, 1516	Foster, C.R
Elkins, J.A 160	Fawzy, I	Foster, L.W 1862
Ellen, C.H	Fearon, W	Foughner, J.T., Jr
Elliott, S.J	Feiler, C.E605, 606	Foutch, D.A 1334, 1646
Ellis, J.R	Fein, J.A	Fowler, J.R 625
Elmadany, M.M	Felix, M.P 1020	Fox, G.L
El Menoufy, M	Felsen, L.B	Foxon, M.B
Elsabee, F	Felske, A	Fradellos, G
El-Sharkawy, A.I	Felszeghy, S.F	Frain, W.E
Elwany, M.H.S	Feng, TT	Franz, L
Engel, Z	Ferris, C.D	Fredberg, J.J
Engels, R.C	Ferritto, J.M	Freund, L.B830
Engin, H	Ficcadenti, G	Freymann, R
Engler, G	Fien, A	Friedman, M 500
Engquist, B	Filho, F.V	Friedrich, H
Engstrom, S.P 1086	Filipich, C	Frieze, P.A 845
Enochson, L 813	Filippi, P.J.T 214, 1230, 1231	Frigeri, C 540
Enserink, B 1097	Finck, H.D 446	Frohrib, D.A
Erickson, L.L	Fine, D.S 1678	Fryer, B.A
Ericsson, L.E	Fink, H.I	Frye, J.L
Eriksson, L.J	Fink, M.R	Fu, H
Eringen, A.C	Finley, T.D	Fuca, T
Eshleman, R.L	Finney, R.H	Fuchs, H.V 1389, 1477
Esmailzadeh, E 1863	Fiorato, A.E 434	Fujii, K 1761

Fujii, Y1607, 1608	Gear, G.W 1701	Gran, C.S 960
Fujimoto, H 1289, 1337	Gebhardt, W 151	Grant, D.A 1291
Fujisawa, F 1665	Geers, T.L	Grant, G.N.C420, 1789
Fujiwara, K	Geissler, W 1640	Greenfield, L.P
Fukano, T	Geller, R.J	Gregory, D.L
Fukazawa, K	Genin, J	Greif, R
Fukuoka, H	George, J	Griffin, M.J 144, 1341, 1342,
Fuller, C.R	George, O.D	1491, 1652
Fullman, D.G	George, P.T	Griffin, O.M 263, 277, 1412
Funahashi, A 1099	Gerardi, T.G	Griffiths, I.D
Fung, Y.C	Gerbert, G	Groeneweg, J.F
Funk, J.G 1871		Groesbeck, D
	Gergely, P 658	
Funnell, W.R	Ghai, R.C	Groom, N.J
Funnell, W.R.J	Gianetti, C.E	Grover, G.K
Furuhashi, T	Giansante, N 24, 375	Grover, L.K
Furukawa, Y	Gillespie, T.D	Grubb, R.L
Fyfe, I.M 1218	Glacel, R.A	Grundmann, H
	Glaser, F.W 604	Grzedzinski, J 809, 1197
	Glassford, E.J	Guedes Soares, C
G	Glenn, P.K	Guendelman-Israel, R 213
	Glynn, C.C	Guibert, J.P
	Gmelin, B 1488	Guillemette, R
Gagnon, L.W 1784	Go, J.C	Gunter, E.J 892, 1129, 1193,
Gahlau, H	Godden, W.G	1195, 1196, 1512
Gahn, B.M	Goel, B.S 1319	Gunter, R.R
Galaitsis, A.G612	Goff, R.J 1410	Gunzburger, M.D 907
Gallo, J.G 1797	Goglia, G.L	Gupta, B.P 126
Galloway, W.J 385, 463, 640	Gokhale, P.S 1001	Gupta, K
Gallus, H.E	Gold, B	Gupta, N.K 1712
Gambhir, M.L 1785	Goldsmith, W	Gupta, R.S 1282
Gamer, U 1823	Good, M.C	Gupta, U.S 1616
Gamon, M.A 1725, 1854	Goodall, R.E 1153	Guruswamy, P 1312
Ganapathi, K417	Goodling, E.C 906	Guthrie, K.M
Garba, J.A	Gordon, D.F 526	Gutierrez, J.A 791
Garg, D.P	Gordon, J.T., Jr 1016	Gutierrez, R.H430, 707
Garg, V.K	Gordon, R.W137, 1844	Gutowski, T.G1487, 1764
Garinther, G.R	Gorman, D.J	Guyader, J.L1391, 1466
Garner, H.C 458	Gosele, K 245	Guyenne, T.D 1690
Garnier, J.L	Gösele, R	
Garrott, W.R	Gosele, U 245	
Gartenbaum, E	Gossmann, E 1548	н .
Gasch, R 165, 186, 365	Gostling, R.J 160	••
Gasper, R	Goto, N 1582	
Gasparetto, M 862	Gottlieb, C.L	Habault, D 1230, 1231
Gasparini, D.A	· · · · · · · · · · · · · · · · · · ·	
	Gouda, Z.M	Habercom, G.E., Jr 204
Gatchel, S.G 1601	Gould, P.L	Habercom, G.E., Jr
Gatchel, S.G	Gould, P.L 1550	Habermann, H 968, 1604
Gates, R.M	Gould, P.L	Habermann, H
Gates, R.M	Gould, P.L. 1550 Goyder, H.G.D. 196 Grabitz, G. 282	Habermann, H.
Gates, R.M	Gould, P.L	Habermann, H

Hadden, J.A 473	Hatano, M.M 1675	Higginson, G.R 1489
Haddow, J.B 1246, 1812	Hatano, S 686	Higginson, R.F 1848
Hadjian, A.H 1876	Haug, A.J	Hight, T.K
Hafen, B.E	Haug, E.J., Jr 908, 1705, 1807	Hilber, H.M 767
Hafez, M.M	Haupt, U	Hildebrandt, C322
Hagg, A.C	Hauschild, W 165	Hill, J.T 891
Hahn, E.J	Hawkings, D.L	Hill, R.E192
Hales, F.D	Hayama, S	Hillquist, R.K 639
Hall, W.E., Jr	Hayashi, T	Hilton, D.A191, 1846
Hall, W.J	Hayden, R.E 744	Himelblau, H
Halle, H	Hayes, G.G 481	Hinchey, M.J
Haller, M.N	Hayon, R 1575	Hinckley, D
Halliwell, D.G 470	Hays, W.W 1749	Hipkin, E.L
Halloran, J.D	Healey, A.J	Hiromitsu, S 1216
1497, 1591	Heard, J.M 1708	Hirose, A
Halvorsen, W.G 380, 1758	Heard, W.L., Jr	Ho, CH342
Hamdan, S.M	Hearn, N.D 1048	Ho, W.F 1395
Hamel, P	Hearn, T.C 194	Hobbs, R.E
Hamilton, J.F 855	Hedaya, M.T 667	Hoch, R.G
Hammann, J	Hedrick, J.K	Hodges, D.H 616
Hananel, A.S 1685	Heggie, A.S	Hodgson, T.H 932
Hancock, R.N 20	Heidmann, M.F 349, 745, 1013	Hoenlinger, H
Hanff, E.S 678	Heimann, A	Hoesly, R.L646
Hansbo, S 1765	Heimann, B 1220	Hofmann, L.G
Hansson, J.E 145	Heimbigner, G 1589	Hofmeister, L.D
Happe, A	Heimbold, G.K	Holder, B.W
Harada, H	Hein, W 1204	Holliday, B.G 863, 1484, 1558
Harari, A	Heinrich, H.G 794	Holmer, C.I
Harder, T	Heissing, B 955	Holmes, A.G 1356, 1884
Hardtke, H.J 1219	Heller, R	Holmes, H.K 863, 1484, 1558
Hare, R.B 612	Helms, H	Holmes, P.J 378, 499, 1105
Harnik, E 677	Hemmig, F.G	Holmes, R
Harp, J.A 1510	Henderson, F.M210	Holoyen, S 1449
Harper, P.M., Sr 1835	Henderson, H.R 1846	Holzweissig, F 1219
Harr, M.E	Henderson, T.D 673	Homans, B 1637
Harris, A.S 1223	Henneke, E.G., II 1770	Honda, A 246
Harris, C.J	Hennig, K	Hong, C 1248
Harris, W.L	Hensing, P.C	Hongo, S
Harrison, E	Herbage, B.S 558	Hood, W.C
Harrison, H.D 1034	Herrara, R.A 788	Hoover, J.W
Hart, G.C 636, 642, 781, 864,	Herrmann, G 266, 830, 1574	Hopkin, A.S 649
. 86 5	Hersh, A.S	Hoppe, G
Hart, J.'t	Herting, D.N 646	Horner, G.C
Hartnett, E.B 496	Hertz, E.V	Horonjeff, R.D
Hartung, C 593	Herzog, W	Horvath, A.J.T
Hartwig, H 1557	Hesselmann, N	Horvath, K
Hashmi, M.S.J 980	Heyman, J.S 1264	Horvay, G
Haslinger, K.H882	Hibner, D.H	Houghton, J.R
Hassall, J	Hibner, D.H	Houser, D.R
Hasselman, T.K 1710	Hidaka, T 694	Housner, G.W 1019, 1222

Huang, C.C	Howell, L.J	Ishii, N. 121, 122, 123 Ishiyama, H. 1445 Ito, H. 1289, 1337 Ito, T. 246 Ito, Y. 1249 Iwahashi, Y. 87 Iwan, W.D. 786, 1091 Iwata, Y. 595 Iwatsubo, T. 623	Jones, C.J.129Jones, D.I.G.974Jones, N.1124Jones, R.1027Jones, R.E.1832Jones, W.L.752Jonsson, H.1894Joppa, P.D.1218Joshi, S.G.1213, 1367
Hudson, D.E. 682 6	Huang, R.C. 1807 Hübner, R. 433 Huckelbridge, A.A., Jr. 1645,		Junger, M.C
Hughes, A. 250 Hughes, T.J.R. 767, 1525, 1526. 1527 Jackson, J.E. 153 Hullender, D. 1351 Jacobson, I.D. 134 Humar, J.L. 780 Jacobson, M.J. 27 Kakad, Y.P. 871 Hundal, M.S. 1839 Jacopues, J.R. 29 Kaliski, S. 934 Hunt, B.I. 146 Jain, D.L. 1233 Kalnins, A. 699 Hunt, N.J. 50 James, A. 1682 Kamal, M.M. 1073 Hussain, F.A. 1455 Janc, C. 1044 Kamash, K.M.A. 181,182, 1354 Hutter, K. 984 Hutter, K. 984 Jachow, F. 969 Kamit, H.A. 1198 Hwang, Y.F. 1435 Jayawant, B.V. 172 Kan, C.L. 229 Jeanpierre, F. 1459 Jachow, F. 990, 991 Kan, W. 1454 Hwang, Y.F. 1435 Jayawant, B.V. 172 Kan, C.L. 229 Jeanpierre, F. 1459 Kan		J	
Hughes, T.J.R. 767, 1525, 1526, 1527, 1527, 1527, 1527, 1527, 1528, 1527, 1528, 1527, 1528			K
Hullender, D. 1351 Jacobson, I.D. 134 Kadala, P.S. 1659 Humar, J.L. 780 Jacobson, M.J. 27 Kakad, Y.P. 871 Hundal, M.S. 1839 Jacobson, M.J. 27 Kakad, Y.P. 871 Hundal, M.S. 1839 Jacobson, M.J. 27 Kakad, Y.P. 871 Hundal, M.S. 1839 Jacobson, M.J. 27 Kalski, S. 934 Hundal, M.S. 1936 Jain, D.L. 1233 Kalnins, A. 699 Hunt, B.I. 146 Jain, D.L. 1233 Kamal, M.M. 1073 Hustan, D. 739 James, P.K. 1775 Kamash, K.M.A. 181, 182, 1354 Huston, R.L. 1656 Janetzke, D.C. 353 Kamel, M.M. 181, 2154 Hutter, K. 984 Jarchow, F. 969 Kamel, H.A. 1198 Hwang, Y.F. 1435 Jayaram, V.D. 969 Kamel, H.A. 198 Hwang, Y.F. 1435 Jayaram, V.D. 969 Kan, C.L.<	Hughes, A		
Hundal, M.S. 1839 Jacques, J.R. 29 Kaliski, S. 934 Hung, S.J. 936 Jain, D.L. 1233 Kalnins, A. 699 Hunt, B.I. 146 Jain, V.K. 1383 Kamal, M.M. 1073 Hurst, N.J. .50 James, P.K. 1775 Kamal, W. 971 Hussain, F.A. 1455 Jan, C. 1044 Kamath, M.P. 51,705 Huston, R.L. 1656 Jan, C. 1044 Kamath, M.P. 51,705 Hutter, K. 984 Jarchow, F. 969 Kamil, H. 937 Hwang, C. 453 Jayaram, V.D. 969 Kamperman, G.W. 816 Hwang, Y.F. 1435 Jayawant, B.V. 172 Kan, C.L. 229 Jeanpierre, F. 1459 Kan, W. 1454 Kanai, K. 1227 Jeanings, D.E. 1630 Kanair, K. 1227 Ibrahim, R.A. 510, 774, 920, Jennings, P.C. 1222, 1334 Kanaya, O. 1002 Ibrahim	Hullender, D 1351	Jacobson, I.D 134	Kadala, P.S 1659
Hurst, N.J. .50 James, A. .1682 Kamal, W. .971 Husak, A.D. .739 James, P.K. .1775 Kamash, K.M.A. .181, 182, 1354 Hussain, F.A. .1455 Jan, C. .1044 Kamat, M.P. .51, 705 Huston, R.L. .1656 Janctow, F. .969 Kamil, H. .937 Hwang, C. .453 Jayaram, V.D. .969 Kam, H. .937 Hwang, Y.F. .1435 Jayawant, B.V. .172 Kan, C.L. .229 Jeanpierre, F. .1459 Kan, W. .1454 Jedryszek, J. .1052 Kanabis, W.G. .648 Jennings, D.E. .1630 Kanai, K. .1227 Ibrahim, R.A. .510, 774, 920, Jennings, P.C. .1222, 1334 Kanai, K. .1227 Ibrahim, S.R. .14, 208, 644 Jha, S.K. .1635, 1636 Kane, T.R. .815 Ikeda, K. .1003 Jhaveri, D.P. .660 Kantola, R.A. .354 Illingworth, R. .169	Hundal, M.S 1839	Jacques, J.R 29	Kaliski, S
Hussain, F.A. 1455 Jan, C. 1044 Kamat, M.P. 51,705 Huston, R.L. 1656 Janetzke, D.C. 353 Kamel, H.A. 1198 Hutter, K. 984 Jarchow, F. 969 Kamil, H. 937 Hwang, C. 453 Jayaram, V.D. 969 Kamperman, G.W. 816 Hwang, Y.F. 1435 Jayawant, B.V. 172 Kan, C.L. 229 Jeanpierre, F. 1459 Kan, W. 1454 4 Jedryszek, J. 1052 Kanabis, W.G. 648 Jedryszek, J. 1052 Kanabis, W.G. 648 Jedryszek, J. 1052 Kanai, A. 595 Ibrahim, R.A. 510, 774, 920, Jennings, P.C. 1222, 1334 Kanai, A. 1227 Jbrahim, S.R. 14, 208, 644 Jha, S.K. 1630 Kane, T.R. 815 Ikeda, K. 1003 Jhaveri, D.P. 660 Kantola, R.A. 354 Illingworth, R. 169 Jillesma, P.J. 130 Kanwal, R.P	Hurst, N.J	James, A	Kamal, W
Hutter, K. 984 Jarchow, F. 969 Kamil, H. 937 Hwang, C. 453 Jayaram, V.D. 969 Kamperman, G.W. 816 Hwang, Y.F. 1435 Jayawant, B.V. 172 Kan, C.L. 229 Jeanpierre, F. 1459 Kan, W. 1454 Jedryszek, J. 1052 Kanabis, W.G. 648 Jendrzejczyk, J.A. 990, 991 Kanai, A. 595 1813 Kanai, K. 1227 Jennings, D.E. 1630 Kanarachos, A. 273 Ibrahim, R.A. 510, 774, 920 Jennings, P.C. 1222, 1334 Kanaya, O. 1002 1072, 1226 Jennings, P.C. 1222, 1334 Kanber, H. 1699 Ibrahim, S.R. 14, 208, 644 Jha, S.K. 1635, 1636 Kane, T.R. 815 Ikeda, K. 1003 Jhaveri, D.P. 660 Kantola, R.A. 354 Illingworth, R. 169 Jillesma, P.J. 130 Kanwal, R.P. 1233 Imachii, K. 121, 122, 123 Johal, L.S. 434 Kao, G.C. 609 I	Hussain, F.A 1455	Jan, C	Kamat, M.P 51, 705
Jeanpierre, F. 1459	Hutter, K	Jarchow, F	Kamil, H937
Jendrzejczyk, J.A. 990, 991, Kanai, A. 595	Hwang, Y.F	Jeanpierre, F 1459	Kan, W
Ibrahim, R.A. .510, 774, 920, 1072, 1226 Jennings, P.C. .1222, 1334 Kanaya, O. .1002 Ibrahim, S.R. .14, 208, 644 Jha, S.K. .1635, 1636 Kane, T.R. .815 Ikeda, K. .1003 Jhaveri, D.P. .660 Kantola, R.A. .354 Illingworth, R. .169 Jillesma, P.J. .130 Kanwal, R.P. .1233 Imaichi, K. .121, 122, 123 Johal, L.S. .434 Kao, G.C. .609 Imam, M.H. .1321 Johannes, J.D. .152 Kao, R. .1324 Inoue, T. .187 Johnson, M.R. .1186 Karbassioun, A. .1318 Ioi, T. .1003 Johnson, W. .141, 1650, 1712 Kargaudas, V. .846 Irie, T. .310 Johnston, D.E. .364, 482 Karkauskas, R. .850 Isada, N. .164 Johnston, J.P. .1392 Karrholm, G. .1765	1	Jendrzejczyk, J.A 990, 991,	Kanai, A595
Ibrahim, S.R. 14, 208, 644 Jha, S.K. 1635, 1636 Kane, T.R. 815 Ikeda, K. 1003 Jhaveri, D.P. 660 Kantola, R.A. 354 Illingworth, R. 169 Jillesma, P.J. 130 Kanwal, R.P. 1233 Imaichi, K. 121, 122, 123 Johal, L.S. 434 Kao, G.C. 609 Imam, M.H. 1321 Johannes, J.D. 152 Kao, R. 1324 Inasaki, I. 743, 1179 Johnson, G. 1657 Kapur, A.D. 534 Inoue, T. 187 Johnson, M.R. 1186 Karbassioun, A. 1318 Ioi, T. 1003 Johnson, W. 141, 1650, 1712 Kargaudas, V. 846 Irie, T. 310 Johnston, D.E. 364, 482 Karkauskas, R. 850 Isada, N. 164 Johnston, J.P. 1392 Karrholm, G. 1765		Jennings, P.C 1222, 1334	Kanarachos, A
Illingworth, R. 169 Jillesma, P.J. 130 Kanwal, R.P. 1233 Imaichi, K. 121, 122, 123 Johal, L.S. 434 Kao, G.C. 609 Imam, M.H. 1321 Johannes, J.D. 152 Kao, R. 1324 Inasaki, I. .743, 1179 Johnson, G. 1657 Kapur, A.D. 534 Inoue, T. .187 Johnson, M.R. 1186 Karbassioun, A. 1318 Ioi, T. .1003 Johnson, W. 141, 1650, 1712 Kargaudas, V. 846 Irie, T. .310 Johnston, D.E. .364, 482 Karkauskas, R. 850 Isada, N. .164 Johnston, G.W. .1843 Karmakar, B.M. .117 Isenberg, J. .981 Johnston, J.P. .1392 Karrholm, G. .1765	Ibrahim, S.R 14, 208, 644	Jha, S.K 1635, 1636	Kane, T.R815
Imam, M.H. 1321 Johannes, J.D. 152 Kao, R. 1324 Inasaki, I. 743, 1179 Johnson, G. 1657 Kapur, A.D. 534 Inoue, T. 187 Johnson, M.R. 1186 Karbassioun, A. 1318 Ioi, T. 1003 Johnson, W. 141, 1650, 1712 Kargaudas, V. 846 Irie, T. 310 Johnston, D.E. .364, 482 Karkauskas, R. 850 Isada, N. 164 Johnston, G.W. 1843 Karmakar, B.M. 117 Isenberg, J. 981 Johnston, J.P. 1392 Karrholm, G. 1765	Illingworth, R 169	Jillesma, P.J 130	Kanwal, R.P 1233
Isada, N. 164 Johnston, G.W. 1843 Karmakar, B.M. 117 Isenberg, J. 981 Johnston, J.P. 1392 Karrholm, G. 1765	Imam, M.H. 1321 Inasaki, I. 743, 1179 Inoue, T. 187	Johannes, J.D. 152 Johnson, G. 1657 Johnson, M.R. 1186	Kao, R. 1324 Kapur, A.D. 534 Karbassioun, A. 1318
	Isada, N	Johnston, G.W	Karmakar, B.M

Kasbekar, P.V 878	Kingery, C	Koyanagi, S
Kascak, A.F 769	Kingsbury, H.B 1102	Kraft, R.E692
Kasemset, C	Kingsland, R.B896	Krag, B334
Kato, Y 1289	Kinnear, P.W 192	Krajcinovic, D 98
Katra, T 1277	Kirk, J.A	Kramer, E
Katsaitis, S 1468	Kirk, R.G	Kreitlow, W
Katto, Y	Kirk, W.P	
		Krenz, G
Katz, R	Kishan, H	Kress, R
Kauffmann, W.M 139, 1339	Kitching, R	Krettek, O
Kaul, M.K	Kiyono, S 1607, 1608	Krieg, R 1668
Kaul, R.K	Kizirnis, S.W 543	Krings, W 1066, 1548
Kausel, E 1763	Klahs, J.W	Krishna, M.B 1351
Kawahara, K 623	Klammert, A 1111	Krishna Murty, A.V 1622
Kawai, R	Klier, H 1878	Krishnamoorthy, G342
Kawai, T	Knoell, A.C 588	Kropp, P.K 592
Kawamo, K	Knofel, L 1242	Krouse, J.K
Kawashima, K 1443	Knothe, K	Krutinis, A
	-	
Kayanickupurathu, J.T 40	Ko, N.W.M 384, 1395, 1733	Krutzik, N
Kaza, K.R.V 690	Kobayashi, S	Ku, A.B
Kearny, C.H 1565	Koch, J.E 806	Kubo, A 1802
Keil, A	Koch, M 1655	Kugler, B.A
Kellenberger, W 684	Koch, W423	Kuist, C.H
Keller, A.C 1274	Kodaira, M 570	Kukreti, A.R 629
Kelley, J	Kodama, Y 1347	Kulak, R.F 1673
Kelley, J.M 657	Koelbel, J.G 917	Kulisiewicz, M 633
Kellogg, R.B 502	Koff, B.L 1674	Kulkarni, P.A 487
Kelly, J.M	Kogure, K	Kulowksi, A
Kampner, J	Kohler, W.E	Kumar, A 416
Kennedy, J.M 1669	Kohn, J.S 691	Kumar, R
Kennett, E.W		
	Kojima, H	Kumar, S 475
Kenton, E 1546, 1719	Kolodziej, R.M552, 553, 554,	Kumar, V
Kerwin, J.E 1684	1497, 1591	Kumar, V.K
Kessler, F.M 1559	Komori, S 1460	Kumbetlian, G
Khetan, R.P712	Komura, Y 1344	Kundert, W.R 817, 1269
Khurasia, H.B 1465	Koopman, G.H	Kunicki, R.G
Kienappel, K 1513	Koopmann, G.H	Kunieda, T 1163
Kiessling, F	Koplik, B	Kunihiro, M 1443
Kiger, S.A	Kordes, E.E	Kunukkasseril, V.X307, 1817
Kik, W 165	Körner, K	Kurihara, M
Kikuchi, K 685	Korner, W	Kurkov, A1296, 1793
Kilmer, R.D	Kortum, W 23	Kuroda, M
Kim, K.H 1680	Koshut, R.J	Kurtz, E.F., Jr 478
Kim, Y.K	Kost, G937	Kvaternik, R.G
Kimball, B.S	Koster, M.P	Kwak, Y.K 1176
Kimball, C.E	Kot, C.A	100 m
Kimsey, K.D 1549	Kotowski, S	
		_
Kimura, A	Kottapalli, S.B.R 536	L
Kimzey, W.F 602	Koutsky, L.J 1492	
King, K.W	Koval, L.R 1845	
King, W.F., III 222, 521, 610	Koyanagi, R.S 671	Laan, J.N 281

LaBarge, W.L	Leonard, R.G. .261, 1709 Leppington, F.G. .1386, 1556 Lesser, M. .1407 Lester, G.M. .1423 Lesueur, C. .1391, 1466 Leung, Y.T. .563 LeVert, F.E. .954 Levine, H.S. .981 Levinson, M. .1341, 1342 Lewis, C.H. .1341, 1342 Lewis, F.M. .1684 Lewis, P.T. .1682 Lewis, R.B. .863, 1484, 1558 Lewis, W.G. .143 Liao, S. .1741 Liard, G. .968, 1604	Lugner, P. 174 Luhrs, R.A. 748 Luisoni, L.E. 582, 872, 1144, 1314 1314 Lujan, R.A. 28 Luke, R.R. 625 Lukkunaprasit, P. 996 Lund, J.W. 1130, 1885, 1888 Lundberg, B. 1407 Lundholm, G. 972 Luttrell, N.W. 1181 Luttwak, G.E. 1103 Lybas, J.M. 341, 709, 710, 1323 Lynch, J.W. 863 Lyon, R.H. 775 Lysmer, J. 1183
Lapins, M	Libai, A	
Laszlo, C.A	Lin, Y.K 243, 452, 1105	Mc
Laudiero, F	Lindberg, H.E	MIC
Laura, P.A.A	Lindner, R	
707, 872, 1144, 1314	Lingener, A	
Laurenson, R.M628	Linscott, B.S	
Law, E.H 473, 1659, 1873	Lionberger, S.R 1792	McCarty, A.M 1207
Law, R 1069	Lippmann, S.A	McCharen, J
Lawdermilt, L.J 1383	Lisewski, W599	McConnell, K.G941
Lawrence, A 1007	Lisnitzer, M	McCormick, R.B893
Lawrence, W.P	Liszka, L	McDaniel, D.M
Lay, S.E 1004	Little, L.M 1410, 1637	McDonald, W.B 1735
Leach, P.G.L	Liu, C.K	McDonough, J.F
Leasure, W.A., Jr 586	Liu, D	McFarland, D.B
Leatherwood, J.D 798 Lebel, D	Liu, HH	McGarvey, J.H
Lee, A 25, 34, 344, 1429,	Liu, W.K1525, 1526, 1527	McGehee, D.Y
1650, 1651	Livolant, M	McGehee, J.R
Lee, J.M 941	Lloyd, A.J.P	McGivern, J.G
Lee, L.C	Lo, H	McGregor, R.M 543
Lee, L.H.N	Lodge, C.G	McGuckin, W.J 249
Lee, P.C.Y 1384	Lofgren, E.V	McIntosh, S.C., Jr
Lee, P.Y.N 1840	Longhouse, R.E 1663	McIvor, I.K 396, 397, 398
Lee, R.A1850, 1851, 1852	Longinotti, D.B 541	McKindra, C.D 1502
Lee, T.H	Lopatowa, H 1154	McKinzie, D.J., Jr 1168
Lee, T.W	Lottero, R.E 1549	McLarty, T.E
Legendre, R	Lou, Y.K 1463	McLarty, T.T
Leipholz, H.H.E9, 912, 1365	Loukakis, T.A 1199	McLaughlin, P.W 1046
Leis, B.N	Love, R.A1229, 1382	McLean, D
Leissa, A.W	. Lu, D.Y	McLean, L.A
Leland, T.J.W	Lu, Y.P	McLean, L.J
Lemnios, A.Z	Lubin, B.T	McNiven, H.D 1532, 1533
Lena, A.L	Luco, J.E	McTasney, R 1769

Macchi, A. . 540 Margolis, D.L. . 635 Meller, T. . 1159 Maccy, D. . 1476 Marino, D. . 840, 949 Mellor, M. . 741 Macinante, J.A. . 867 Mark, W.D. . 1452 Melosin, R.J. . 51 Maciulevičius, D. . 787 Markert, R. . 365 Meltzer, G. . 518 Mackinnon, M.J. . 1666 Maroney, G.E. . 254 Melvin, J.W. . 234, 235, 1654 Maclaughlin, T.F. . 1097 Marriner, J.E. . 513, 514 Melzig-Thiel, R. . 518 Madarame, H. . 1359 Marshall, K.Z. . 319 Merchant, D.H. . 643 Madarame, H. . 1359 Marshall, K.Z. . 319 Merchant, D.H. . 374 Madday, C.J. . 1119 Marshall, K.Z. . 319 Merchant, D.H. . 374 Madday, C.J. . 1119 Marshall, K.Z. . 319 Merchant, D.H. . 374 Madday, C.J. . 1119 Marshall, K.Z. . 319 Merritt, L.D. . 112 Madsw	M MacBain, J.C	Manuelyan, R	Meindl, H.G 220 Meirovitch, L 1228, 1531 Meissner, E 104 Melbourne, W.H 400 Mellander, H 1655
Macinante, J.A. 867 Mark, W.D. 1452 Melosh, R.J. .51 Macclulevičius, D. 787 Markert, R. .365 Meltzer, G. .518 Mackay, J.F.W. 1240 Marmol, R.A. .1754 Melvin, J.W. .234, 235, 1664 Mackinnon, M.J. 1666 Maroney, G.E. .254 Melzig-Thiel, R. .518 Mackay, J.F.W. 1097 Marriner, J.E. .513, 514 Menichello, J.M. .643 Madarame, H. 1359 Marshall, K.Z. .319 Merchant, D.H. .374 Maddox, V. .252 Martin, D.M. .1859 Merchant, D.H. .374 Maddox, V. .252 Martin, G.C. .878 Merritt, J.L. .936 Maskawa, S. .452 März, G. .237 Merritt, F.G. .340 Maezawa, S. .663 Mason, R. .1087 Merritt, F.G. .340 Magnus, R. .442 Massoud, M. .1097 Merson, J.L. .881 Magnus, R. .442 Massoud, M. <td>Macchi, A540</td> <td>Margolis, D.L</td> <td>Meller, T</td>	Macchi, A540	Margolis, D.L	Meller, T
Mackay, J.F.W. 1240 Marmol, R.A. 1754 Melvin, J.W. 234, 235, 1654 Mackinnon, M.J. 1666 Maroney, G.E. .254 Melzig-Thiel, R. .518 Maclaughlin, T.F. 1097 Marriner, J.E. .513, 514 Menichello, J.M. .643 Madarame, H. 1359 Marsh, A.H. 1638 Mente, L.J. .112 Maday, C.J. 1119 Marshall, K.Z. .319 Merchant, D.H. .374 Vaddox, V. 252 Martin, D.M. .1859 Merchant, D.H. .374 Madsen, N.F. 1609 Martin, G.C. .878 Merritt, J.L. .936 Maekawa, S. .452 März, G. .237 Merritt, P.H. .17 Maekawa, S. .452 März, G. .237 Merritt, P.H. .17 Maekawa, S. .452 März, G. .237 Merritt, P.H. .17 Maexawa, S. .463 Massin, A. .1087 Merritt, P.H. .17 Maexawa, S. .465 März, G.	·		
Mackinnon, M.J. 1666 Maroney, G.E. 254 Melzig-Thiel, R. 518 Maclaughlin, T.F. 1097 Marriner, J.E. 513, 514 Menichello, J.M. 643 Madarame, H. 1359 Marsh, A.H. 1638 Mente, L.J. 1112 Maddox, V. 252 Marshall, K.Z. 319 Merchant, D.H. 374 Maddox, V. 252 Martin, D.M. 1859 Merchant, D.H. 936 Maekawa, S. 452 März, G. 237 Merritt, J.L. 936 Maekawa, Z. 132 Masix, A.K. 695 Merritt, R.G. 340 Maezawa, S. 663 Mason, R. 1087 Merson, J.L. 881 Magee, C.L. 1473 Massoud, M. 1071 Mes, M.J. 1107 Magnuson, A.H. 1361 Masuko, M. 1249 Messele, R.F. 484 Magrab, J. 871 Mathews, R.E. 1037 Meyer, R.J. 1508 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 M			
Maclaughlin, T.F. 1097 Marriner, J.E. .513, 514 Menichello, J.M. .643 Madarame, H. 1359 Marsh, A.H. 1638 Mente, L.J. .112 Maday, C.J. 1119 Marshall, K.Z. .319 Merchant, D.H. .374 Vaddox, V. .252 Martin, D.M. .1859 Merchant, H.C. .1016 Madsen, N.F. 1609 Martin, G.C. .878 Merritt, J.L. .938 Maekawa, S. .452 März, G. .237 Merritt, P.H. .17 Maekawa, S. .452 Mäsix, A.K. .695 Merritt, P.H. .17 Maecawa, S. .663 Mason, R. .1087 Merritt, P.H. .17 Maecawa, S. .663 Mason, R. .1087 Merritt, P.H. .17 Maecawa, S. .663 Mason, R. .1087 Merritt, P.H. .17 Magee, C.L. .1473 Mason, S. .79, 1865 Mertt, D.W. .765 Magnus, R. .422 Massoud, M. .1071			
Madarame, H. 1359 Marsh, A.H. 1638 Mente, L.J. 112 Maday, C.J. 1119 Marshall, K.Z. 319 Merchant, D.H. 374 Vaddox, V. 252 Martin, D.M. 1859 Merchant, H.C. 1016 Maekawa, S. 452 Märin, G.C. 878 Merritt, J.L. 936 Maekawa, Z. 132 Maslix, A.K. 695 Merritt, P.H. 17 Maecawa, S. 663 Mason, R. 1087 Merson, J.L. 881 Magee, C.L. 1473 Masri, S.F. 79, 1865 Merrott, R.G. 340 Magnuson, A.H. 1361 Masuko, M. 1071 Mes, M.J. 1107 Mahlingam, S. 1437 Mathews, F.H. 56 Mettler, E. 1520 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, R.J. 1590 Mahnoud, M.S. 7 Matsuda, T. 883 Meyer, R.J. 1590 Mahrenholtz, O. 593 Matsukura, Y. 148 Meyer, W.L. <td></td> <td></td> <td></td>			
Maday, C.J. 1119 Marshall, K.Z. 319 Merchant, D.H. 374 Waddox, V. 252 Martin, D.M. 1859 Merchant, D.H. 1016 Madsen, N.F. 1609 Martin, D.M. 1859 Merchant, D.H. 1016 Madexawa, S. 452 Marin, G.C. 878 Merritt, J.L. 938 Maexawa, Z. 132 Masik, A.K. 695 Merritt, R.G. 340 Maezawa, S. 663 Mason, R. 1087 Merson, J.L. 881 Magee, C.L. 1473 Massik, A.K. 695 Merritt, R.G. 340 Magnus, R. 442 Massoud, M. 1071 Messon, J.L. 881 Magnus, A. 1361 Massud, M. 1249 Messale, R.F. 484 Magrab, E.B. 14462 Mathews, F.H. 56 Mettler, E. 1520 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, R.J. 1590 Mahmoud, M.S. 7 Matsuda, T. 883 Meyer, W.L.			
Waddox, V. 252 Martin, D.M. 1859 Merchant, H.C. 1016 Madsen, N.F. 1609 Martin, G.C. 878 Merritt, J.L. 936 Maekawa, S. 452 März, G. 237 Merritt, P.H. 17 Maekawa, Z. 132 Maslix, A.K. 695 Merritt, P.H. 17 Maexawa, S. 663 Mason, R. 1087 Merson, J.L. 881 Magee, C.L. 1473 Massoud, M. 1071 Merson, J.L. 861 Magnus, R. 442 Massoud, M. 1071 Mes, M.J. 1107 Magnuson, A.H. 1361 Masuko, M. 1249 Messale, R.F. 484 Margab, E.B. 1462 Mathews, F.H. 56 Mettler, E. 1520 Mahling, J. 871 Mathon, R. 1893 Meyer, J. 1508 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, T.R. 193 Mahmoud, M.S. 7 Matsuda, T. 883 Meyer, W.L. 1740 <td></td> <td></td> <td></td>			
Maekawa, S. 452 März, G. 237 Merritt, P.H. 17 Maekawa, Z. 132 Maslix, A.K. 695 Merritt, R.G. 340 Maezawa, S. 663 Mason, R. 1087 Merson, J.L. 881 Magee, C.L. 1473 Masri, S.F. 79, 1865 Mertz, D.W. 765 Magnus, R. 442 Massoud, M. 1071 Mes, M.J. 1107 Magnuson, A.H. 1361 Masuko, M. 1249 Messale, R.F. 484 Magrab, E.B. 1462 Mathews, F.H. .56 Mettler, E. 1520 Mahin, S.A. 390, 788 Mathon, R. 1893 Meyer, R.J. 1508 Mahmoud, M.S. .7 Matsuda, T. 883 Meyer, R.J. 1590 Mahmoud, M.S. .9 Matsuda, T. 883 Meyer, W.L. 1740 Mahrenboltz, O. 593 Matsukura, Y. 187 Mico, W. 1357 Maier, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. <td></td> <td></td> <td></td>			
Maekawa, Z. 132 Maslix, A.K. 695 Merritt, R.G. 340 Maezawa, S. 663 Mason, R. 1087 Merson, J.L. 881 Magee, C.L. 1473 Masri, S.F. 79, 1865 Mertz, D.W. 765 Magnus, R. 442 Massoud, M. 1071 Mes, M.J. 1107 Magnus, R. 442 Massoud, M. 1071 Mes, M.J. 1107 Magnus, R. 442 Massoud, M. 1071 Mes, M.J. 1107 Magnus, R. 442 Massoud, M. 1071 Messale, R.F. 484 Magrab, E.B. 1462 Mathews, R.B. 1037 Meyer, J. 1508 Mahiling, S. 1437 Mathows, R.B. 1037 Meyer, J. 1508 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, T.R. 193 Mahmoud, M.S. 7 Matsud, T. 883 Meyer, R.J. 1740 Mahrenholtz, O. 593 Matsui, N. 148 Meyer, W.L. 1740	Madsen, N.F 1609	Martin, G.C	Merritt, J.L
Maezawa, S. 663 Mason, R. 1087 Merson, J.L. 881 Magee, C.L. 1473 Masri, S.F. 79, 1865 Mertz, D.W. 765 Magnus, R. 442 Massoud, M. 1071 Mes, M.J. 1107 Magnuson, A.H. 1361 Masuko, M. 1249 Messale, R.F. 484 Magrab, E.B. 1462 Mathews, F.H. 56 Mettler, E. 1520 Mahligam, S. 1437 Mathews, R.E. 1037 Meyer, J. 1508 Mahin, S.A. 390, 788 Matkon, R. 1893 Meyer, R.J. 1590 Mahmoud, M.S. 7 Matsuda, T. 883 Meyer, T.R. 193 Mahmoud, M.S. 7 Matsuda, T. 883 Meyer, W.L. 1740 Mahrenholtz, O. 593 Matsui, N. 148 Meyer, W.L. 1740 Mair, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mair, R.I. 471 Matsunota, Y. 1247 Michalak, C.H.<		•	
Magee, C.L. 1473 Masri, S.F. .79, 1865 Mertz, D.W. .765 Magnus, R. 442 Massoud, M. 1071 Mes, M.J. .1107 Magnuson, A.H. 1361 Masuko, M. 1249 Messale, R.F. .484 Magrab, E.B. 1462 Mathews, R.H. .56 Mettler, E. .1520 Mahlingam, S. 1437 Mathon, R. .1037 Meyer, J. .1508 Mahin, S.A. .390, 788 Mathon, R. .1893 Meyer, R.J. .1590 Mahmoud, M.S. .7 Matsuda, T. .883 Meyer, W.L. .1740 Mahrenholtz, O. .593 Matsui, N. .148 Meyers, G.J. .1618 Maidanik, G. .503 Matsukura, Y. .187 Michalak, C.H. .887 Mains, R.M. .128 Matsumoto, K. .1139 Michalek, A. .522 Mair, R.I. .471 Matsuoka, Y. .1247 Michalopoulos, C.D. .81 Majumdar, B.C. .486 Mattura, T. .1790 <td></td> <td></td> <td></td>			
Magnus, R. 442 Massoud, M. 1071 Mes, M.J. 1107 Magnuson, A.H. 1361 Masuko, M. 1249 Messale, R.F. 484 Magrab, E.B. 1462 Mathews, F.H. 56 Mettler, E. 1520 Mahalingam, S. 1437 Mathews, R.E. 1037 Meyer, J. 1508 Mahin, J. 871 Mathon, R. 1893 Meyer, R.J. 1509 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, T.R. 193 Mahmoud, M.S. .7 Matsuda, T. 883 Meyer, W.L. 1740 Mahrenholtz, O. .593 Matsui, N. 148 Meyers, G.J. 1618 Maidanik, G. .503 Matsukura, Y. 187 Michalak, C.H. 887 Maier, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mair, R.I. .471 Matsuoka, Y. 1247 Michalek, A. 522 Mair, R.I. .471 Matsuoka, Y. 1247 Michalopoulos, C.D. .81 Majumdar, B.C. .486 Matsuura, M. </td <td></td> <td></td> <td></td>			
Magnuson, A.H. 1361 Masuko, M. 1249 Messale, R.F. 484 Magrab, E.B. 1462 Mathews, F.H. 56 Mettler, E. 1520 Mahalingam, S. 1437 Mathews, R.E. 1037 Meyer, J. 1508 Mahig, J. 871 Mathon, R. 1893 Meyer, R.J. 1590 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, T.R. 193 Mahmoud, M.S. 7 Matsuda, T. 883 Meyer, W.L. 1740 Mahrenholtz, O. 593 Matsui, N. 148 Meyers, G.J. 1618 Maidanik, G. 503 Matsukura, Y. 187 Miao, W. 1357 Mair, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mair, R.I. 471 Matsumoto, K. 1139 Michalak, C.H. 887 Majumdar, B.C. 486 Matsuura, M. 1305 Michalke, A. 522 Makisi, F.I. 1401, 1403 Matsuura, T. 1790 Mickle, M.H. .7 Makiki, L.R. 461 Matta, R.K.			
Magrab, E.B. 1462 Mathews, F.H. 56 Mettler, E. 1520 Mahalingam, S. 1437 Mathews, R.E. 1037 Meyer, J. 1508 Mahig, J. 871 Mathon, R. 1893 Meyer, R.J. 1590 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, T.R. 193 Mahmoud, M.S. 7 Matsuda, T. 883 Meyer, W.L. 1740 Mahrenholtz, O. 593 Matsui, N. 148 Meyers, G.J. 1618 Maidanik, G. 503 Matsukura, Y. 187 Miao, W. 1357 Maier, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mains, R.M. 128 Matsumoto, K. 1139 Michalek, A. 522 Mair, R.I. 471 Matsuoka, Y. 1247 Michalopoulos, C.D. 81 Majumdar, B.C. 486 Matsuura, M. 1305 Michel, U. 784, 1477 Makarewicz, R. 1082, 1084 Matsuura, T. 1790 Mickle, M.H. .7 Makilik, L.R. 461 Matta, R			
Mahig, J. 871 Mathon, R. 1893 Meyer, R.J. 1590 Mahin, S.A. 390, 788 Matkowsky, B.J. 3 Meyer, T.R. 193 Mahmoud, M.S. 7 Matsuda, T. 883 Meyer, W.L. 1740 Mahrenholtz, O. 593 Matsui, N. 148 Meyers, G.J. 1618 Maidanik, G. 503 Matsukura, Y. 187 Miao, W. 1357 Maier, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mains, R.M. 128 Matsumoto, K. 1139 Michalke, A. 522 Mair, R.I. 471 Matsuoka, Y. 1247 Michalopoulos, C.D. 81 Majumdar, B.C. 486 Matsuura, M. 1305 Michel, U. .784, 1477 Makarewicz, R. 1082, 1084 Matsuura, T. 1790 Mickle, M.H. .7 Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. .1777, 1778, 1779 Mallik, A.K. 100, 125, 555 </td <td></td> <td></td> <td></td>			
Mahin, S.A. .390, 788 Matkowsky, B.J. .3 Meyer, T.R. .193 Mahmoud, M.S. .7 Matsuda, T. .883 Meyer, W.L. .1740 Mahrenholtz, O. .593 Matsui, N. .148 Meyers, G.J. .1618 Maidanik, G. .503 Matsukura, Y. .187 Miao, W. .1357 Maier, R.E. .1042 Matsumoto, H. .570, 1247, 1298 Michalak, C.H. .887 Mains, R.M. .128 Matsumoto, K. .1139 Michalke, A. .522 Mair, R.I. .471 Matsuoka, Y. .1247 Michalopoulos, C.D. .81 Majumdar, B.C. .486 Matsuura, M. .1305 Michel, U. .784, 1477 Makarewicz, R. .1082, 1084 Matsuura, T. .1790 Mickle, M.H. .7 Makdisi, F.I. .1401, 1403 Matsuzaki, Y. .287 Midha, A. .1806 Malik, L.R. .461 Matta, R.K. .223 Miele, A. .1777, 1778, 1779 Mallik, A.K. .100, 125, 555 Matthia, H. .1117 Miksch, H. .955 <t< td=""><td></td><td></td><td>Meyer, J 1508</td></t<>			Meyer, J 1508
Mahmoud, M.S. .7 Matsuda, T. .883 Meyer, W.L. .1740 Mahrenholtz, O. .593 Matsui, N. .148 Meyers, G.J. .1618 Maidanik, G. .503 Matsukura, Y. .187 Miao, W. .1357 Maier, R.E. .1042 Matsumoto, H. .570, 1247, 1298 Michalak, C.H. .887 Mains, R.M. .128 Matsumoto, K. .1139 Michalak, C.H. .887 Mair, R.I. .471 Matsumoto, K. .1139 Michalak, C.H. .887 Mair, R.I. .471 Matsucka, Y. .1247 Michalopoulos, C.D. .81 Majumdar, B.C. .486 Matsuura, M. .1305 Michel, U. .784, 1477 Makarewicz, R. .1082, 1084 Matsuura, T. .1790 Michel, W.H. .7 Makdisi, F.I. .1401, 1403 Matsuzaki, Y. .287 Midha, A. .1806 Malik, L.R. .461 Matta, R.K. .223 Miele, A. .1777, 1778, 1779 Mallik, A.K. .100, 125, 555 Matthai, H. .1117 Miksch, H. .955 <t< td=""><td></td><td></td><td></td></t<>			
Mahrenholtz, O. 593 Matsui, N. 148 Meyers, G.J. 1618 Maidanik, G. 503 Matsukura, Y. 187 Miao, W. 1357 Maier, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mains, R.M. 128 Matsumoto, K. 1139 Michalke, A. 522 Mair, R.I. 471 Matsuoka, Y. 1247 Michalopoulos, C.D. 81 Majumdar, B.C. 486 Matsuura, M. 1305 Michel, U. .784, 1477 Makarewicz, R. 1082, 1084 Matsuura, T. 1790 Mickle, M.H. .7 Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. 1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. .955 Malthan, J.A. 1441 Matthiesen, R.B. 679 Mikulas, M.M., Jr. 1202 Malthan, J.A. 74 Mattu, R.K. 1037 Mikulas, M.M., Jr. 1202 Mamode, A. <td></td> <td></td> <td></td>			
Maidanik, G. 503 Matsukura, Y. 187 Miao, W. 1357 Maier, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mains, R.M. 128 Matsumoto, K. 1139 Michalke, A. 522 Mair, R.I. 471 Matsuoka, Y. 1247 Michalopoulos, C.D. 81 Majumdar, B.C. 486 Matsuura, M. 1305 Michel, U. .784, 1477 Makarewicz, R. 1082, 1084 Matsuura, T. 1790 Mickle, M.H. .7 Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. 1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. .955 Malsch, H. 1441 Matthiesen, R.B. 679 Mikulas, M.M., Jr. 1202 Malthan, J.A. .74 Mattu, R.K. 1037 Mikulcik, E.C. .14 Malvern, L.E. .59 Matzen, V.C. 1532, 1533 Miller, C.A. .697 Mancuso, J.R.			
Maier, R.E. 1042 Matsumoto, H. 570, 1247, 1298 Michalak, C.H. 887 Mains, R.M. 128 Matsumoto, K. 1139 Michalke, A. 522 Mair, R.I. 471 Matsuoka, Y. 1247 Michalopoulos, C.D. 81 Majumdar, B.C. 486 Matsuura, M. 1305 Michel, U. 784, 1477 Makarewicz, R. 1082, 1084 Matsuura, T. 1790 Mickle, M.H. .7 Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. 1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. .955 Malsch, H. 1441 Matthiesen, R.B. 679 Mikulas, M.M., Jr. 1202 Malthan, J.A. 74 Mattu, R.K. 1037 Mikulcik, E.C. .14 Malvern, L.E. .59 Matzen, V.C. 1532, 1533 Miller, C.A. .697 Mamode, A. .626 Mayes, I.W. .1356, 1884 Miller, D.R. .320 Mancus			
Mair, R.I. 471 Matsuoka, Y. 1247 Michalopoulos, C.D. .81 Majumdar, B.C. 486 Matsuura, M. 1305 Michel, U. .784, 1477 Makarewicz, R. 1082, 1084 Matsuura, T. 1790 Mickle, M.H. .7 Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. .1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. .955 Malsch, H. 1441 Matthiesen, R.B. .679 Mikulas, M.M., Jr. .1202 Malthan, J.A. .74 Mattu, R.K. .1037 Mikulcik, E.C. .14 Malvern, L.E. .59 Matzen, V.C. .1532, 1533 Miller, C.A. .697 Mamode, A. .626 Mayes, I.W. .1356, 1884 Miller, D.R. .320 Mancuso, J.R. .902 Mayes, W.H. .863, 1484, 1558 Miller, H.M. .714			
Majumdar, B.C. 486 Matsuura, M. 1305 Michel, U. .784, 1477 Makarewicz, R. 1082, 1084 Matsuura, T. 1790 Mickle, M.H. .7 Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. 1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. .955 Malsch, H. 1441 Matthiesen, R.B. .679 Mikulas, M.M., Jr. .1202 Malthan, J.A. .74 Mattu, R.K. .1037 Mikulcik, E.C. .14 Malvern, L.E. .59 Matzen, V.C. .1532, 1533 Miller, C.A. .697 Mamode, A. .626 Mayes, I.W. .1356, 1884 Miller, D.R. .320 Mancuso, J.R. .902 Mayes, W.H. .863, 1484, 1558 Miller, H.M. .714	_		
Makarewicz, R. 1082, 1084 Matsuura, T. 1700 Mickle, M.H. .7 Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. 1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. .955 Malsch, H. 1441 Matthiesen, R.B. .679 Mikulas, M.M., Jr. 1202 Malthan, J.A. 74 Mattu, R.K. 1037 Mikulcik, E.C. .14 Malvern, L.E. 59 Matzen, V.C. 1532, 1533 Miller, C.A. .697 Mamode, A. 626 Mayes, I.W. 1356, 1884 Miller, D.R. .320 Mancuso, J.R. 902 Mayes, W.H. 863, 1484, 1558 Miller, H.M. .714	*		
Makdisi, F.I. 1401, 1403 Matsuzaki, Y. 287 Midha, A. 1806 Malik, L.R. 461 Matta, R.K. 223 Miele, A. 1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. 955 Malsch, H. 1441 Matthiesen, R.B. 679 Mikulas, M.M., Jr. 1202 Malthan, J.A. 74 Mattu, R.K. 1037 Mikulcik, E.C. 14 Malvern, L.E. 59 Matzen, V.C. 1532, 1533 Miller, C.A. 697 Mamode, A. 626 Mayes, I.W. 1356, 1884 Miller, D.R. 320 Mancuso, J.R. 902 Mayes, W.H. 863, 1484, 1558 Miller, H.M. 714			and the second s
Malik, L.R. 461 Matta, R.K. 223 Miele, A. 1777, 1778, 1779 Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. 955 Malsch, H. 1441 Matthiesen, R.B. 679 Mikulas, M.M., Jr. 1202 Malthan, J.A. 74 Mattu, R.K. 1037 Mikulcik, E.C. 14 Malvern, L.E. 59 Matzen, V.C. 1532, 1533 Miller, C.A. 697 Mamode, A. 626 Mayes, I.W. 1356, 1884 Miller, D.R. 320 Mancuso, J.R. 902 Mayes, W.H. 863, 1484, 1558 Miller, H.M. 714			
Mallik, A.K. 100, 125, 555 Matthai, H. 1117 Miksch, H. .955 Malsch, H. 1441 Matthiesen, R.B. .679 Mikulas, M.M., Jr. .1202 Malthan, J.A. .74 Mattu, R.K. .1037 Mikulcik, E.C. .14 Malvern, L.E. .59 Matzen, V.C. .1532, 1533 Miller, C.A. .697 Mamode, A. .626 Mayes, I.W. .1356, 1884 Miller, D.R. .320 Mancuso, J.R. .902 Mayes, W.H. .863, 1484, 1558 Miller, H.M. .714			
Malsch, H. 1441 Matthiesen, R.B. 679 Mikulas, M.M., Jr. 1202 Malthan, J.A. 74 Mattu, R.K. 1037 Mikulcik, E.C. 14 Malvern, L.E. 59 Matzen, V.C. 1532, 1533 Miller, C.A. 697 Mamode, A. 626 Mayes, I.W. 1356, 1884 Miller, D.R. 320 Mancuso, J.R. 902 Mayes, W.H. 863, 1484, 1558 Miller, H.M. 714			
Malvern, L.E. .59 Matzen, V.C. .1532, 1533 Miller, C.A. .697 Mamode, A. .626 Mayes, I.W. .1356, 1884 Miller, D.R. .320 Mancuso, J.R. .902 Mayes, W.H. .863, 1484, 1558 Miller, H.M. .714	Malsch, H 1441	Matthiesen, R.B679	Mikulas, M.M., Jr 1202
Mamode, A			
Mancuso, J.R			
WIGHUGUL, N	Mandadi, R	Maymon, G 702	Miller, N.A 672
Mangiavacchi, A 1778, 1779 Mayo, R.A			
Mani, R	Mani, R 823		
Mann, F.I			
Mann, R.A			
Manor, H. 1284 Meggitt, D.J. 966 Milton, J.E. 112 Manos, P. 647 Mehta, R.K. 1755 Minagawa, S. 803			
Mantegazza, C.CP			

Mingori, D.L	Morrow, C.T	Nakra, B.C
Mirandy, L 820	Mortell, M.P 804	Nappi, A
Mirizzi, N	Mortland, K	Narita, Y
Misra, A.K	Moseley, P	Narkis, Y
Misra, J.C	Moss, G.F	Nash, P.T
Mitchell, E.E 858	Mote, C.D., Jr 584, 1449, 1540	Nashif, A.D
Mitchell, G.C783	Motsinger, R.E692	Nassar, E.M
Mitschke, M	Mozo, B.T 462	Nath, Y
Mittal, A.K 1518	Mruk, G.K552, 553, 554,	Natham, E
Mittendorf, S.C 557	1497, 1591	Nau, J.M
Miura, H	Muir, R.S	Nayfeh, A.H 705, 1136, 1450,
Miwa, S	Muirhead, V.U 673, 674, 721	1816
Mixson, J.S 1012	Mukherjee, A415	Neal, E
Miyashita, M	Mukherjee, P.R 1643	Nefske, D.J
Mizoguchi, K	Mukherjee, S	Neighbors, A.J.K 1796
Mizushima, Y	Müller, D	Nelson, F.C
Mizutani, K	Müller, J	Nelson, I
Mlakar, P.F	Munaswamy, K 1642	Nelson, P.M
Mochizuki, M	Murata, S	Nelson, R.L
Modi, V.J	Murman, E.M	Neubert, V.H 1601
Moe, G	Murphy, G 509 Murphy, H.L 1567	Neumann, R
Moffitt, R.C	Murphy, J.A	Newbrough, D.E
Mohanty, A.K 1029	Murray, L.O 371, 483, 484	Newman, M
Mohanty, B.P	Murthy, S.S 490	Newmark, N.M
Mohr, R.L	Murthy, V.R	Newsom, D.E
Mohri, Y	Murty, A.V.K 490	Ng-A-Qui, N.T
Moiseev, N 689	Myers, T.T	Ni, C
Mojaddidy, Z1469	Mykytow, W.J 444	Nicholas, J.C
Molnar, A.J		Nichols, R.S 42
Montgomery, C.J 1333, 1335		Nicholson, D.W1570, 1571, 1700
Montgomery, L.D 1175	N	Nicol, S.W 814, 1515, 1516
Montgomery, S.T241		Niedzielski, J
Moodie, T.B 1812	·	Nielsen, J.P 1014
Mook, D.T 1816	Nabel, E	Nigam, S.P
Moore, E.F	Nachman, A	Nikolakopoulou, G 1624
Moore, M 816	Nachtigal, C.L1499, 1867, 1868	Nilsson, A.C
Morado, J.Y 1702	Naft, M.H	Nishiwaki, N
Moran, B	Nagai, K	Nissim, E
Moran, D.D	Nagai, T	Nix, H.D
Moran, M.J	Nagasaka, I	Noda, K
Morfey, C.L	Nakagawa, N 623	Nogami, T
1738, 1739	Nakahara, I 570, 1247, 1298	Nogis, R
Mori, E	Nakai, T	Nogis, R
Morita, N	Nakamachi, K 556	Nohara, M
Morosow, G		
	Nakamura, A 989	Nolle, H 240
Morr, H 1596		Nolle, H
	Nakamura, A 989	

Noonan, C	Otsuki, Y 1761	Penterson, C.A946
Noor, A.K	Oved, Y	Penzes, L.E 106, 1036
Nordby, K.S	Overway, N	Penzien, J 1332
Nordlin, E.F	Overway,	Pepitone, T.R 1056
Norgan, R		Perera, W.G 842
Norling, R.L	P	Perkins, J
Norman, C.D	r	Perl, E 532
Norris, D.M 197		Perreira, N.D
Norris, T.R 612	Paas, J.E692	Perrella, W.M., Jr 1855
Nunn, R	Pacejka, H.B	Perrin, R
Nulli, H	Packer, M.B	Perrone, N
	Packman, P.F	Persson, U
•	Padovan, J	Perumalswami, P.R 1399, 1400
0	Page, V.R	Peschier, T.D
	Paidoussis, M.P 93, 561	Peterka, F
Obal, M.W	Pakstys, M.P	Peterson, D 627
Oblizajek, K.L316	Pallett, D.S	Petre, A
O'Brien, J	Palmer, M.E	Petrovski, J
Oesterle, R.G	Pampreen, R.C 890	Pettigrew, M.J 1875
	Pampura, D.P	Petyt, M
Ogawa, K	Pan, M	Petzold, L
Ogawa, T	Pao, Y	Pfaffinger, D.D
Ogg, J.S	Pandit, S.M 11, 773	Pfizenmaier, E 35, 784
O'Hearne, C.S	Pang, S.H	Pfützner, H
Ohga, J	Pappas, M	Phelps, R.L
Ohmata, K	Pappas, M.S	Philippin, G.A
Ohta, M	Parashes, P.T	Phillips, E.H 1685
Ohta, Y	Pardee, W.J	Phillips, R.G 1697
Ohya, A	Parekh, V.N	Pick, R.J
Oie, S	Parikh, P.D 437	Pickert, J 597
Okamoto, T	Park, R.B 1749	Pickett, G.F1229, 1382, 1506
Okayama, T	Parker, A.T 1768	Piegert, R 597
O'Keefe, E 1773	Parker, L.V 1619	Pierce, D
O'Keeffe, J.M 1162	Parker, R 1307	Piersol, A.G 225, 759, 1237
Okrent, D 1717	Parker, W.H	Pierson, W.D 1628, 1629
Okumura, I	Parks, D.M 716	Pies, D
Oladunni, J.O 428	Parrott, T.L	Pietrucha, J
Olas, A 424	Parsons, K.C 1491	Pilkey, W.D 1192, 1586, 1829,
Oleson, M.W 506	Partom, Y	1830, 1834, 1889
Olsen, N.L	Partridge, J.R566	Piltner, R 1554
Olsson, U	Passerello, C.E	Piner, R.J 1732
Olunloyo, V.O.S 984	Pastorel, H 1071	Pinkham, C.W 781, 864, 865
Orlandea, N	Patel, M.H	Piotrowski, E
Orlik-Ruckemann, K.J 678	Patten, J	Pisarski, J.J
Ormsbee, A.I	Patterson, J.H., Jr	Pish, R.H
Osborn, J.E	Pavithran, S	Piskorz, Z
Oshita, J 694	Pearson, R	Piszczek, K 1092
Osman, M.O.M	Pearsoon, A.J	Pittroff, H
Ostiguy, G.L	Pecelli, G	Pixton, T.A.H
Ota, H	Pelz, W319	Pizzigoni, B

Platin, B.E 611	Radziszewski, B 1062	Reismann, H
Platzer, M.F	Rajamani, A	Remington, P.J 749
Plimmer, R.N.A 1605	Rajpaul, V.K26	Renfro, E.M
Plotkin, K.J1238, 1239	Ramachandran, S.V 1143	Renger, A 1093
Pollard, J.D 671	Ramaiah, G.K 1315	Rennie, A.J1276, 1848
Pollard, M.G 157	Ramakrishna, B.S 1446	Rennison, D.C 102
Pollin, I	Ramakrishnan, R 307	Rentz, P.E
Pollman, E 1350	Raman, P.V	Repa, B.S 67
Pollock, A	Ramberg, S.E	Reynolds, W.R403
Pombo, J.L	Ramboz, J.D 671	Ribner, H.S 1241
Poon, D.T	Ramesh, C.K 849	Ricci, J.J 484
Popov, E.P 1023	Ramkumar, R.L	Rice, E.J 525, 606, 1135
Popplewell, N 1240, 1243	Rammerstorfer, F.G 704	Richards, T.H 563
Posehn, M.R 64, 65	Ramsden, J.N 1509	Richards, T.R
Posey, J.W	Ramsey, K	Richardson, H.H 162, 1182
Post, M.J	Ramsey, M 455	Richardson, J.D 1318
Postlethwaite, B.C 333	Raney, J.P	Richardson, M.H 1214
Postnikow, O.K 1110	Ranlet, D	Richardson, R.S.H 240
Potter, J.R 1786	Rao, B.V.A	Rickley, E.J
Pottinger, M.G319	Rao, D.K	Riddle, D.W 453
Powell, G.H213, 1610	Rao, G.V	Rieger, N.F489, 1132
Powell, R.G 1849, 1850,	Rao, J.S 91, 415, 418, 419, 1824	Riessberger, K 167
1851, 1852	Rao, M.V 1312	Riffel, R.E 1791
Powers, W.R 1102	Rao, N.S	Riganti, R1089, 1756
Prabhakaran, R	Rao, S.S 873, 1282, 1501, 1831	Riley, C.M.E 978
Prasad. B	Rao, U.N 555	Rimrott, U.A
Prathap, G 413, 1313, 1444,	Rasmussen, G 818	Ringo, B.C 693
1467	Rautenberg, M 1295	Rio, R.A
Pratt, H.K	Ravenhall, R 826	Ripianu, A
Pratt, R.L	Rawtarti, S 1465	Rita, A.D 1027
Prause, R.H	Ray, D	Rivin, E.I
Price, G.V 964, 965, 1281	Razzacki, S.T	Rizk, M.H
Price, M.H	Rebel, J	Robbins, D.H
Price, W.G 189, 1362, 1783	Rebiere, J.P	Robbins, F.F., Jr 1008
Pursel, H.D 1095	Rebora, B	Roberson, R.E
Pustejovsky, M	Recklies, S	Roberts, J.B 1090, 1211
Putter, S	Redd, L.T	Roberts, J.W 1226
	Reding, J.P	Robinson, D.W
	Reddingius, N.H211, 1075	Robinson, J.H., Jr
R	Reddy, C.P	Robson, J.D 181, 182, 1354
	Reddy, J.N	Rodger, I.A
Rahinawitz M.D. 369 360	Reding, J.P	Roger, K.L
Rabinowitz, M.D	Rees, D	Rogers, D.O
Radcliffe, C.J	Reethof, G	Rogers, J.D
Råde, L	Reich, M	Rogers, J.L., Jr
Rader, J	Reif, Z	Rogers, P.H
Rades, M	Reilly, M.J	Rogers, R.J
Radford, R.W 876	Reimherr, G.W 1718	Rohde, S.M
Radwan, H.R	Reinl, H	Rojahn, C 679
	,	,, 0

Romander, C.M. 1748 Romo-Organista, M.P. 654 Rönitz, R. 889 Rosenberg, Z. 1103, 1430 Rosendahl, R. 1559 Roskam, J. 673, 674, 721 Ross, C.A. 112, 507, 1453 1827 Ross, W. 16 Rossettos, J.N. 532 Rossini, T. 537 Rotem, A. 953 Rothe, P.H. 1033 Rouch, K.E. 1886 Rowan, W.H. 54	Sanderson, N. 1120 Sandler, B. 982 Sankar, S. 105, 1804 Santini, P. 1250, 1411, 1691 Saravanja-Fabris, N. 1866 Sarin, S.L. 1872 Sarpkaya, T. 278 Sarrailhe, S.R. 1048 Sasaki, K. 1417 Sass, D.E. 991 Sato, K. 565, 1121 Sato, T. 1417 Sattaripour, A. 183 Satter, M.A. 1141 Saucier, K.L. 230	Schwerdtfeger, H. 1350 Schwiesow, R.L. 1771 Sciarra, J.J. 1529 Sclavounos, P.D. 1199 Scott, R.A. .776, 919 Scotto, F.L. 1043 Seabase, P.P. 313 Sebastian, J.D. 459 Seed, H.B. .1183, 1401, 1403 Seeman, D.R. 1014 Seffell, B.F., Jr. 1041 Segawa, Y. 1665 Segel, L. 317 Seidman, H. 219 Seifert, K.D. 936
Roy, T.K 438	Saurenman, H.J	Seifert, P
Rubin, M 1717	Savell, C.T	Seiffert, H
Rubinstein, N 740	Saxena, S.K	Seiffert, U.W
Rudnick, I	Scavuzzo, R.J 577	Seiler, J.P 1266
Runstadler, P.W., Jr 1033	Schaefer, J.W	Seireg, A
Rus, L	Schapiro, S.M	Sekimoto, M 1298
Rusnak, T.J	Scharton, T.D	Seleghim, P
Russell, H.G	Schauble, C.C	Sellappan, R
Trussen, Tr. 11	Scheel, J.W 1095	Senda, Y
	Scheible, D	Seniwongse, M 1857
S	Schetky, L.M	Sensburg, O
•	Schibli, U	Sentek, J
	Schiehlen, W.O 149	Serravalli, W 825
Saalfeld, M 1160	Schiff, A.J	Sessarego, J.P 1254
Saari, D.P 794	Schippers, P	Sethna, P.R 910
Sachs, G 446	Schmid, G948	Settles, W.T
Sachs, H.K 176	Schmid, W	Sevy, R.W 1724
Sachse, W	Schmidt, KJ	Seymour, B.R 804
Sackman, J.L 293, 1244,	Schmidt, W.E	Shackelford, J.F
1837	Schmit, L.A	Shah, P.C 1067, 1174
Sadek, M.M	Schmitz, F.H	Shahabadi, A
Saffell, B.F., Jr	Schoeller, K	Shahady, P.A
Safford, F.B	Schomer, P.D1410, 1559, 1637	Shapiro, W
Saini, S.S	Schomer, R.D	Shapton, W.R 1074
Saito, H	Schönfeld, S 516	Sharma, C.B 1288
Sajiki, A	Schoultz, M.B	Sharma, D.K 1022, 1174
Sakai, H 1002	Schramm, G 249	Sharma, R.K 805, 1751
Salamone, D.J 1195	Schreyer, H.L 41, 782, 1670	Sharp, B.H 1239
St. Hilaire, A.O 810		
Sakaguchi, K 346	Schriever, H	Sharp, J.D
Jakaguciii, K	Schriever, H	Sharp, R.S
Sakata, T	Schubert, D.M 589 Schuerman, J.A 1046	Sharp, R.S
	Schubert, D.M 589	Sharp, R.S

0, 5,0	0: 5	
Shaw, E.A.G 528	Singh, R1277, 1278	Speakman, J.D.: 1849, 1850, 1851,
Shaw, L	Singh, S.P	1852
Shaw, L.L	Sinha, S.K	Spencer, A.J.M83, 84, 85
Shaw, L.M	Sinhasan, R	Spencer, R.H
Shawa, O.M	Sisto, F	Spera, D.A
Shawki, G.S.A 1760	Sjoflot, L	Sperling, A
Shayo, L.K	Slabinski, V.J	Spiro, H
Shearer, G.R	Slibar, A	Sridhar, K
Sheer, R.E	Skrikerud, P.E 1408	Sridhar, S 1450, 1816
Sheikh, R.M 1433	Slone, R.M., Jr	Srinath, H 417
Sheinman, I	Smalley, A.J 1152, 1472, 1568,	Srinivasan, A.V 1792
Shen, C.N	1587, 1755, 1883	Srinivasan, K1499, 1867, 1868
Shende, R.W 488	Smallwood, D.O62, 1422	Srinivasan, M.G 98
Shepherd, R 1745	Smigielski, P 544	Srinivasan, P 1213, 1367
Sherrer, V.C 927	Smilowitz, R 1026, 1336	Srinivasan, R.S 1143, 1642
Shiau, L.C	Smith, C.C 885, 1176, 1340	Stahle, C.V
Shiba, F	Smith, C.D 1076	Stalnaker, R.L
Shibata, H	Smith, H.W 673, 674, 721	Stanley, G.M
Shimada, K	Smith, J.H	Stanley, R.A 607
Shimizu, T 1179	Smith, J.S 1470	Stansfeld, J.T 884
Shimogo, T 1781, 1782, 1874	Smith, N	Stanway, R 184
Shimojima, H	Smith, Z.P967	Starr, E.A
Shin, Y.S	Smulfin, J.I 652	States, J.D 1409
Shiozaki, S 596	Sneddon, M.D 856	Steele, J.M 1267
Shirakawa, K 1148	Snow, R 1069	Stein, S
Shirk, I.A	Snowdon, J.C 853	Steinberg, D.S 297, 707, 872,
Shirley, E.C	Snyder, W.J	
Shivakumar, K.N 1622	Snyman, J.A 1060	1063 Steinborn, H 165
Shivamoggi, B.K	Soderman, P.R	Stella, R
Shladover, S.E		
	Soedel, W 1278, 1377, 1475	Stengel, R.F
Shrivastava, S.K924	Sofrin, T.G	Stensson, G 1894
Shu, T	Sofronie, R	Stepanishen, P.R 381, 931, 1808
Shunmugavel, P 170	Sohre, J.S	Stephen, R.M
Sierakowski, R.L59, 507, 1453,	Solaini, A.V	Stephens, D.G 638, 863, 1484,
1827	Solomon, S.G 1232	1558
Sigelmann, R.A 407	Solomon, K.A 1717	Sternberg, R.L527
Simmons, H	Sommer, J	Stevens, C.L 192
Simmons, P.E 641	Soni, S.R	Stevens, R.A 192
Simonian, S	Sonnenburg, P.N 594	Stevenson, R 1207
Simons, D.H 1427	Sonoda, N	Stewart, E.C 451
Simpson, A 8, 279, 403, 911	Sonoda, S	Stewart, E.C 1481
Simpson, I.C 1583	Soper, W.G	Stewart, R.M
Sinacori, J.B 821		
	Sorgatz, U	Stiffler, A.K
Sinclair, J.H	Sosa, F	Stoker, J.R 716,, 1509
Sindelar, F.L64	Sozen, M.A	Stokey, W.J
Singh, A.K	Sozen, M.A	Stolberg, A.L
Singh, D.V	Spagnoto, R	Stone, J.R 1083
Singh, K	Spalding, G.R 1833	Stott, S.J 1212
Singh, M 176	Spanos, PT 1091	Stoughton, R.L716
Singh, M.P	Sparkes, C	Stravinskas, S

Strenkowski, J.S 925, 1829,	Szostak, H.T	Thomas, D.L 1439
1889	Szymani, R	Thomas, E.S
Strickland, W.S		Thomas, J
Striem, H.L	_	Thomet, M.A
Stringas, E.J	Т	Thompson, D.E
Strong, B.R., Jr		Thompson, G.D
Strother, C	Table MM 201	Thompson, W.C
Strothman, W 166	Tabba, M.M	Thompson, W.E
Struble, D	Tabor, F.H	Thomsen, K.K
Stryczek, S	Tadjbakhsh, I	Thomson, B
Stühler, W	Taft, C.K	Thormann, J
Su, T.C	Tagart, S.W., Jr 1094	Thornton, E.A
Suematsu, Y	Tagata, G	Thornton, P.H
Suggs, C.W	Tagg, R.W	Threlfall, D.C
Suhubi, E.S	Tait, J.N	Tijdeman, N
Sullivan, D.F	Takagi, S	Tillou, F.M
Sullivan, J.W	Takahashi, H	Ting, L
Sullivan, P.A	Takahashi, S 410, 556, 1445	Tobe, T
Sullivan, T.L	Takamatsu, Y	Todd, E.S
Sun, C.T	Takano, E	Tokel, H
Sung, S.H 696	Takano, K	Tominari, N
Sunnersjo, C.S	Takatsu, N	Tomlinson, G.R 1349
Suss, S	Takeda, S	Tonnesen, J
Sutherland, G.H	Takeuchi, R	Topper, T.H
Sutton, L.R	Talmadge, R.D	Tordion, G.V900
Sutton, T	Tam, P.K.Y	Torvik, P.J
Suzuki, K 410, 556, 1445	Tamura, A	Townley, G.E
Suzuki, N	Tanaka, H	Townsend, M.A
Suzuki, S	Tanaka, K	Townsend, W.H 665
Suzuki, SI	Tanaka, N 595	Toyoda, M 1251
Svalbonas, V 699	Tanaka, T 402	Traill-Nash, R.W 460
Swaim, R.L	Tani, J 1826	Tree, D.R
Swamidas, A.S.J 1817	Tani, M	Trella, T 1087
Swaminadham, M	Tanimoto, N 402	Trigg, N.E
Swaminathan, M	Tanner, R 1881	Trippett, R.J
Swanger, H.J 1742	Tappert, F.D 1706	Trn, R.M628
Swansson, N.S 834	Taylor, H.R	Troger, H 180
Sweet, A.L 276	Taylor, P.W	Troha, W.A 1769
Swick, D.A	Taylor, R 1167	Troxell, D.E 739
Swift, M.R 1360, 1361	Taylor, R.E	True, D.G
Syed, A.A	Tene, Y 1825	True, H.C
Sylvestre, Y	Teplitzky, A.M	Tsai, N.C666
Symonds, P.S 979, 1566, 1750	Terauchi, Y	Tsai, N.C 1038
Syring, R.P 1628, 1629	Termuehlen, H	Tsay, CS
Szadkowski, A 1062	Teshima, T 1344	Tseng, W.S 666, 1038
Szadkowski, J 1058	Tessarzik, J	Tso, W.K
Szelag, D	Tessarzik, J.M 1883	Tsui, C.Y
Szemplinska-Stupnicka, W 1517	Tessmann, R.K	Tsujimoto, Y
Szewczyk, V.M 1737	Tester, B.J	Tsztoo, D.F657
Szewczyk, V.M 1738, 1739	Tezcan, S.S 1746	Tu, K
·		

Tucker, A.I. 837 Varadhi, S.N. 1649 Ward, D.W. 1494, 1558 Tucker, J.R. 1728 Varna, P.K. 475 Ward, E.D. 321, 1709 Turhan, D. 939 Vaughan, V.L. 793 Washizu, K. 1761 Turkstra, C.J. 264 Vause, C.R. 343, 422 Wasserman, Y. 283, 1800 Turmouli, S.R. 814 Varlock, D.J. 435 Watanabe, T. 103, 663, 1809 Turnbuli, S.R. 814 Varloch, D.J. 435 Watanabe, T. 103, 663, 1809 Turnbuli, S.R. 814 Vendhan, C.P. 579 Watson, H., Jr. 1433 Turner, E.W. 732 Verdon, J.M. 298, 299 Watson, J.H. 1698 Turstin, W. 73, 2021, 1426 Verschoore, R. 318 Weaver, D.S. 1810, 1811 Tuten, J.M. 1659 Verschoore, R. 318 Weaver, D.S. 1810, 1811 Tuten, J.M. 1659 Verge, E. 1649 Weber, O. 363 Twerdosz, F. 997 Vijayakumar, K. 1315 Weeks, G.E. 1620 Wegner, T. 997 Twend, L.W. 717, 1325 Vijayakumar, K. 1315 Weeks, G.E. 1620 Vijayakumar, K. 1316 Weigner, F. 997 Vijayakumar, K. 1310 Weigner, F. 997 Vijayakumar, K. 1300 Weidlinger, P. 995, 986 Weidlinger, P. 99		•	and the second s
Turhan, D. 9.39			
Turkstra, C.J. 264 Vause, C.R. 343,422 Wasserman, Y. 283,1800 Turmbull, S.R. 814 Vendhan, C.P. 579 Watson, H., Jr. 1433 Turner, E.W. 732 Verdon, J.M. 298,299 Watson, J.H. 1698 Turner, M.R. 726 Vered, M. 389 Westerrill, W.H. 469 Tustin, W. 73, 202, 1426 Verschoore, R. 318 Weaver, D.S. 1810, 1811 Turen, J.M. 1659 Vey, E. 1649 Weber, O. 363 Twendochlib, M. 1496 Viljayargshavan, A. 632 Wegner, T. 997 Twerdochlib, M. 1496 Villalaz, P.A. 771 Wenger, T. 997 Twerdochlib, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Tyrill, J.P. 1795 Visanapuu, A. 1004 Weidelnhamer, G.H. 785 Twerdochlib, M. 1496 Volla, F.E. 888 Weidlinger, P. 985,98 Tzafestas, S.G. 1372 Vik, F.			
Turmbull, S.R.			
Turner, E.W. 732 Verdon, J.M. 298, 299 Watson, H., Jr. 1438 Turner, E.W. 732 Verdon, J.M. 298, 299 Watson, J.H. 1698 Turner, M.R. 726 Vered, M. 389 Weatherill, W.H. 459 Tustin, W. 73, 202, 1426 Verschoore, R. 318 Weaver, D.S. 1810, 1811 Tuten, J.M. 1659 Vey, E. 1649 Weber, O. 363 Twardosz, F. 997 Vijayakumar, K. 1315 Weeks, G.E. 1620 Tweed, L.W. 717, 1325 Vijayaraghavan, A. 632 Wegner, T. 997 Twerdochlib, M. 1496 Villalaz, P.A. 771 Wehage, R. 1330 Twill, J.P. 1795 Visnapuu, A. 1004 Weidenhamer, G.H. 786 Tzafestas, S.G. 1372 Vik, F. 888 Weidlinger, P. 985, 985 Vo, P.T. 1300 Weingold, H.D. 811 Vogt, W.G. 7 Weir, D.H. 1711 U Volin, R.H. 1413 Weisser, R. 1096 Von Buseck, C.R. 1078 Weiburn, D.B. 5658 Überall, H. 382, 1232 Voy, C. 1184 Welbourne, E.R. 1098 Uchvadia, F. 79 Udwadia, F. 77 Uffer, F. 77 Ugai, Y. 1507 Uginičius, P. 382 Ujihashi, S. 570 Wada, B.K. 4,634, 895 Upton, R. 1273 Waggoner, S.A. 1089 Wells, R.A. 1229, 1382 Ujihashi, S. 570 Wada, H. 962 Wells, R.A. 1229, 1382 Valer, D. 977 Walden, H. 562 Westervelt, W.W. 1504 Valer, D. 977 Valer, J. 977			
Turner, E.W. 732 Verdon, J.M. 298, 299 Watson, J.H. 1698 Turner, M.R. 726 Vered, M. 389 Weatherill, W.H. 459 Tustin, W. 73, 202, 1426 Tustin, W. 73, 202, 1426 Verschoore, R. 318 Weaver, D.S. 1810, 1811 Tuten, J.M. 1659 Vey, E. 1649 Weeker, C. 363 Twardosz, F. 997 Vijayakumar, A. 632 Wegner, T. 997 Twerdochilib, M. 1496 Vijayaraghavan, A. 632 Wegner, T. 997 Twerdochilib, M. 1496 Vijayaraghavan, A. 632 Wegner, T. 997 Twerdochilib, M. 1496 Vijayaraghavan, A. 632 Wegner, T. 997 Twerdochilib, M. 1496 Vijayaraghavan, A. 632 Wegner, T. 997 Weidenhamer, G.H. 785 Tzafestas, S.G. 1372 Vik, F. 888 Vo, P.T. 1300 Vejt, W.G. 77 Weit, D.H. 1711 U Volin, R.H. 1413 Weissner, R. 1096 Vogt, W.G. 77 Weit, D.H. 1711 U Volin, R.H. 1413 Weissner, R. 1096 Weitsman, Y. 57 Voofglahn, U. 523 Webourn, D.B. 568 Überall, H. 382, 1232 Voy, C. 1184 Welbourne, E.R. 1068 Uchiyamada, T. 1163 Udwadia, F. 79 Udwadia, F.E. 1022, 1067, 1174 Uffer, F. 77 Ugai, Y. 1507 UginiCius, P. 382 Ujhashi, S. 570 Un, W.K. 1395 Wada, H. 962 Upton, R. 1273 Walden, H. 962 Walden, H. 560 Westervelt, W.W. 1366 Walker, D.D. 31 Walker, D.D. 31 Walker, D.D. 331			
Turstin, W. 73, 202, 1426 Vered, M. 389 Weatherill, W.H. 459 Tustin, W. 73, 202, 1426 Vey, E. 1649 Weyer, D.S. 1810, 1811 Tutten, J.M. 1659 Vey, E. 1649 Weyer, C. 363 Twardosz, F. 9.97 Vijayakumar, K. 1315 Weeks, G.E. 1620 Tweed, L.W. 717, 1325 Vijayaraghavan, A. 632 Wegner, T. 997 Tweedochilb, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Twill, J.P. 1795 Visnapuu, A. 1004 Weidenhamer, G.H. 785 Tzafestas, S.G. 1372 VIk, F. 888 Weidlinger, P. 985, 986 Vo, P.T. 1300 Weingold, H.D. 811 U Volin, R.H. 1413 Weir, D.H. 171 Volin, R.H. 1413 Weitsman, Y. 57 VonGlahn, U. 523 Welbourn, D.B. 568 Uchiyamada, T. 1163 Udwadia, F. 79 Udwadia, F. 77 Ugai, Y. 507 Ugai, Y. 507 Uginfčius, P. 382 Ujihashi, S. 570 Un, W.K. 1395 Upton, R. 1273 Wadg, B.K. 4, 634, 895 Upton, R. 1273 Wade, B.K. 4, 634, 895 Upton, R. 1273 Waldern, H. 562 Waldern, H. 565 Weater, D. 382 Westervett, W.W. 1606 Wellbourne, E.R. 1028 Wells, R.A. 1229, 1382 Wells, R.A. 1229, 1382 Wells, R.B. 199 Wendroff, B. 563 Weater, D. 382 Westervett, W.W. 1603 Walker, D. 337 Wells, R.N. 1664 Waldern, D. 337 Wells, R.N. 1665 Waldern, D. 337 Wells, R.N. 1665 Waldern, D. 337 Wells, R.N. 1664 Waldern, D. 337 Weitham, E.M. 144, 1652 Valdern, J. 729 Waldern, D. 337 Weitham, E.M. 144, 1652 Valdern, J. 729 Waldern, D. 337 Weitham, E.M. 144, 1652 Valdern, P.C. 338 Walter, D. 338 Weitham, R. 34, 760, 1012 Walker, N.D. 337 White, J.L. 729 White, J.L. 729 White, J.L. 729 White, J.L. 729 Waldern, M. 366 Van De Vegte, J. 1257 Vandern, K. 721 Wang, C.Y. 1672 Willey, J.F. 225, 652 Wang, J.C. 338 Willer, J.L. 948 Wi			
Tustin, M. 73, 202, 1426 Verschoore, R. 318 Weaver, D.S. 1810, 1811 Tutten, J.M. 1659 Vey, E. 1649 Weber, O. 363 Twardosz, F. 997 Vijayakumar, K. 1315 Wesks, G.E. 1620 Tweed, L.W 717, 1325 Vijayaraghavan, A. 632 Wegner, T 997 Twardochilb, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Twardochilb, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Twardochilb, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Twardochilb, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Twardochilb, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Weigner, T 997 Welderhamer, G.H. 1850 Vop, P.T. 1300 Weigner, P. 985, 986 Weignold, H.D. 811 Vogt, W.G. 7. 7 Wert, D.H. 1711 U Volin, R.H. 1413 Weissner, R. 1096 Weitsman, Y. 57 VonGlahn, U. 523 Webourn, D.B. 568 Überall, H. 382, 1232 Uchiyamada, T. 1163 Udwadia, F 79 Udwadia, F 79 Udwadia, F 79 Udwadia, F 1022, 1067, 1174 Uffer, F 77 Ugai, Y. 1507 Uginičius, P. 382 Ujihashi, S. 570 Wada, B. K. 4634, 895 Upron, R. 1273 Wagoner, S.A. 1008 Wendler, B.H. 594 Upton, R. 1273 Walker, D. G. 31 Walker, D. G. 32 Weitzer, J. 929 Wendler, B.H. 502 Walker, D. G. 32 Weitzer, J. 929 Wendler, B.H. 503 Wetzer, J. 929 Wendler, B.H. 503 Wetzer, J. 929 Wendler, B.H. 504 Weitzer, J. 929 Wendler, B.H. 504 Weitzer, J. 929 Wendler, B.H. 504 Weitzer, J. 929 Weitzer, J.			
Tuten J.M. 1659			Weatherill, W.H 459
Twardosz, F. 997 Vijayaraghavan, K. 1315 Weeks, G.E. 1620 Tweed, L.W. 717, 1325 Vijayaraghavan, A. 632 Wegner, T. 997 Twerdochilb, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Twill, J.P. 1795 Visapuu, A. 1004 Weidenhamer, G.H. 785 Tzafestas, S.G. 1372 Vik, F. 888 Weidlinger, P. 985, 986 Vo, P.T. 1300 Weingold, H.D. 811 Vogt, W.G. 77 Weir, D.H. 171 Volin, R.H. 1413 Weissner, R. 1096 von Buseck, C.R. 1078 Weitsman, Y. 57 VonGlahn, U. 523 Welbourn, D.B. 568 Uberall, H. 382, 1232 Voy, C. 1184 Welbourne, E.R. 1068 Uchiyamada, T. 1163 Udwadia, F.E. 1022, 1067, 1174 Uffer, F. 77 Ugai, Y. 1507 Uginičius, P. 3822 Ujihashi, S. 570 Uginičius, P. 3825 Upton, R. 1273 Wada, B.K. 4, 634, 895 Wada, H. 962 Wajcefeld, J. 977 Westcott, M.E. 1486 Walker, D.Q. 31 Westcott, M.E. 1486 Vaidya, P.G. 1870 Validya, N.G. 1001 Valentin, R.A. 988 Van Blaricum, P.J.C. 432 Vance, J.M. 1358, 1754 Vandam, K. 721 Vandam, K. 721 Vandam, F.L. 1084 Vann Blaricum, P.J.C. 432 Vance, J.M. 1358, 1754 Vandam, K. 721 Vandam, F.L. 1084 Vann Blaricum, P.J.C. 432 Vance, J.M. 1358, 1754 Vandam, K. 721 Vandam, F.L. 618 Vann, W.P. 47 Vandam, K. 197 Vandam, K. 197 Vandam, F.L. 618 Vann, W.P. 47 Vandam, F.L. 618 Vann, W.P. 419 Vann, F.C. 538 Ville, R.D. 639 Ville, R.M. 618 Ville, R.M. 618 Veils, P.A. 771 Veils, P.P. 77 Veils, P.P. 77 Veils, P.A. 771 Veils, P.A. 771 Veil, P.A. 771 Veil, P.A. 77			Weaver, D.S1810, 1811
Tweed, L.W. 717, 1325 Vijayaraghavan, A. 632 Wegner, T. .997 Twerdochlib, M. 1496 Villalaz, P.A. .771 Wehage, R. .380 Twelfl, J.P. 1795 Visnapuu, A. .1004 Weidenhamer, G.H. .785 Tzafestas, S.G. 1372 Vilk, F. .888 Weidlinger, P. .985, 986 Vop, C. 1380 Weiglold, H.D. .811 .981 .985, 986 Word, W.G. .7 Weir, D.H. .171 .995, 986 .985, 986 Word, W.G. .7 Weiglold, H.D. .811 .981 .985, 986 Word, W.G. .7 Weis, D.H. .171 .995, 986 .985, 986 Word, W.G. .7 Weis, R.A. .198 .985, 986 .985, 986 Word, W.G. .7 Yolf, R.H. .1413 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 .985, 986 <td< td=""><td>Tuten, J.M 1659</td><td>Vey, E 1649</td><td>Weber, O</td></td<>	Tuten, J.M 1659	Vey, E 1649	Weber, O
Twerdochlib, M. 1496 Villalaz, P.A. 771 Wehage, R. 1380 Twill, J.P. 1795 Visnapuu, A. 1004 Weidenhamer, G.H. 785 Tzafestas, S.G. 1372 Vik, F. 888 Weildlinger, P. 9.895, 986 Vo, P.T. 1300 Weingold, H.D. 811 Vogt, W.G. .7 Weir, D.H. .171 Uberall, H. 382, 1232 VonGlahn, U. 523 Welbourn, D.B. 568 Überall, H. 382, 1232 Voy, C. 1184 Welbourn, E.R. 1068 Uchiyamada, T. 1163 Welch, C.R. 45 Udwadia, F. .79 Weller, W.H. 239 Udwadia, F. .79 Weller, W.H. 239 Uginičius, P. 382 Waberski, A. 1819 Wells, R.A. 1229, 1382 Ujihashi, S. .570 Wada, B.K. 4, 634, 895 Wendref, B. .594 Upton, R. 1335 Wada, B.K. 4, 634, 895 Wendref, B. .594 <t< td=""><td>Twardosz, F 997</td><td>Vijayakumar, K 1315</td><td>Weeks, G.E 1620</td></t<>	Twardosz, F 997	Vijayakumar, K 1315	Weeks, G.E 1620
Twill, J.P. 1795	Tweed, L.W717, 1325	Vijayaraghavan, A 632	Wegner, T
Tzafestas, S.G. 1372 VIk, F. 888 Weidlinger, P. .985,986 Vo, P.T. 1300 Weingold, H.D. .811 U Volin, R.H. 1413 Weir, D.H. .171 Vollor, R.H. 1413 Weissner, R. 1096 von Buseck, C.R. 1078 Weltsman, Y. .57 Uberall, H. .382, 1232 VonGlahn, U. .523 Welbourne, E.R. 1068 Uchiyamada, T. .1163 Welch, C.R. .45 Welch, C.R. .45 Udwadia, F. .79 Weldwalia, F. .1068 Weller, W.H. .239 Uffer, F. .77 Waller, D.D. Wells, R.M. .1293 .382 Uginičius, P. .382 Waberski, A. .1819 Wells, R.M. .129 .182 Upton, R. .1273 Wada, B.K. .4 634,895 Wen, Y. .656 Upton, R. .1273 Wada, H. .962 Wendler, B.H. .594 Upton, R. .1273 Wada, H. .962	Twerdochlib, M 1496	Villalaz, P.A	Wehage, R
U Vo, P.T. 1300 Weingold, H.D. 811 U Vogit, W.G. 7 Weir, D.H. 171 Volin, R.H. 1413 Weissner, R. 1096 Überall, H. 382,1232 Voy, C. 1184 Welbourn, D.B. 568 Überall, H. 382,1232 Voy, C. 1184 Welbourne, E.R. 1068 Udwadia, F. 1022, 1067, 1174 W Wells, R.W. 239 Udwadia, F. 779 Wells, R.M. 239 Ugin, Y. 1507 Wals, R.A. 1293 Ugin, Y. 1507 Wada, B.K. 4,634,895 Wells, R.W. 1506 Ujihashi, S. 570 Wada, H. 962 Wendrer, B.H. 594 Upton, R. 1273 Waggoner, S.A. 1008 Wester, J. 929 Wajcfeld, J. 977 Wester, J. 929 Walker, B. 547, 1234 Wester, J. 929 Vaidya, N.G. 1001 Walker, N.D. 637 White, J.L. 729	Twill, J.P 1795	Visnapuu, A 1004	Weidenhamer, G.H 785
U Vogt, W.G. .7 Weir, D.H. .171 U Volin, R.H. 1413 Weissner, R. 1096 Won Buseck, C.R. 1078 Weitsman, Y. .576 Überall, H. 382, 1232 Voy, C. 1184 Welbourn, D.B. .568 Überall, H. 382, 1232 Voy, C. 1184 Welbourn, D.B. .568 Üdwadia, F. .192 Welbourn, D.B. .568 Welbourn, D.B. .568 Udwadia, F. .79 Welder, C.R. .45 Welbourne, E.R. .1068 Uffer, F. .77 Wells, R.W. .1229 .382 Wells, R.W. .1229 .1382 Ujinishis, S. .570 Wada, H. .962 Wender, B.H. .594 .594 Upton, R. .1273 Wagerled, J. .977 Westcott, M.E. .486 V Walden, H. .502 Westervelt, W.W. .803 Walker, D.D. .351 Westervelt, W.W. .803 Vaidya, N.G. .001 Walke	Tzafestas, S.G 1372	V1k, F	Weidlinger, P
U Volin, R.H. 1413 Weissner, R. 1096 von Buseck, C.R. 1078 Weitsman, Y. 57 VonGlahn, U. 523 Welbourn, D.B. 568 Überall, H. 382, 1232 Voy, C. 1184 Welbourn, D.B. 568 Üchiyamada, T. 1163 Welch, C.R. 45 Udwadia, F. 79 Weller, W.H. 239 Udwadia, F.E. 1022, 1067, 1174 W Weller, W.H. 239 Uffer, F.		Vo, P.T	Weingold, H.D 811
Von Buseck, C.R. 1078 Veitsman, Y. 57 VonGlahn, U. 523 Veitsman, Y. 568 Uberall, H. 382, 1232 Voy, C. 1184 Uchiyamada, T. 1163 Udwadia, F. 79 Udwadia, F. 79 Udwadia, F. 77 Ugai, Y. 1507 Uginičius, P. 382 Ujihashi, S. 570 Ughon, R. 1373 Upton, R. 1273 Waler, B. 585 Waler, B. 587 Valcaitis, R. 324, 760, 1012 Valdya, N.G. 1010 Valdya, P.G. 1870 Valdya, P.G. 1870 Valdya, P.G. 1870 Valden, H. 502 Valder, H. 1548 Van Blaricum, P.J.C. 432 Vandem, K. 721 Vandem, K. 1064 Vanden, J. 725 Vandem, S. 1267 Vandem, K. 721 Vandem, J. M. 1358, 1754 Vandem, J. M. 1368 Vann, W.P. 47 Vanningham, F. L. 618 Vann, W.P. 47 Vanningham, F. L. 618 Vand, Y.S. 1384 Veiler, J. 1880 Viller, J. 1974 Villey, J. 1975 Villey, J. 1974 Villey, J. 1974 Villey, J. 1974 Villey, J. 1975	•	Vogt, W.G	Weir, D.H 171
Überall, H. .382, 1232 Von, C. .1184 Welbourn, D.B. .568 Überall, H. .382, 1232 Voy, C. .1184 Welbourne, E.R. .1068 Uchiyamada, T. .1163 Welch, C.R. .45 Udwadia, F. .79 Weller, W.H. .239 Udwadia, F.E. .1022, 1067, 1174 Weller, W.H. .239 Uffer, F. .77 Wells, R.A. .1229, 1382 Ugai, Y. .1507 Wells, R.A. .1229, 1382 Ujinlashi, S. .570 Wada, B.K. .4, 634, 895 Wen, Y. .655 Un, W.K. .1395 Wada, B.K. .4, 634, 895 Wen, Y. .655 Upton, R. .1273 Wagoner, S.A. .1008 Wendler, B.H. .594 Walcer, J. .977 Westervelt, W.W. .180 Walker, B. .547, 1234 Westervelt, W.W. .180 Walker, B. .547, 1234 Westervelt, W.W. .180 Vaidaya, N.G. .1001 Walker, N.D. .637 White, R.N. </td <td>U</td> <td>Volin, R.H 1413</td> <td>Weissner, R 1096</td>	U	Volin, R.H 1413	Weissner, R 1096
Überall, H. 382, 1232 Voy, C. 1184 Welbourne, E.R. 1068 Uchiyamada, T. 1163 Welch, C.R. 45 Udwadia, F. 79 Weller, W.H. 239 Udwadia, F.E. 1022, 1067, 1174 W Wellford, L.C. 1703 Uffer, F. 77 Wells, R.A. 1229, 1382 Ugai, Y. 1507 Wells, R.M. 1506 Uginičius, P. 382 Waberski, A. 1819 Wells, R.M. 19 Ujihashi, S. 570 Wada, B.K. 4, 634, 895 Wen, Y. 655 Un, W.K. 1395 Wada, H. 962 Wendler, B.H. 594 Upton, R. 1273 Waggoner, S.A. 1008 Wenderff, B. 53 Wahl, F. 585 Wester, B. 547, 1234 Westcott, M.E. 1486 V Walder, B. 547, 1234 Wetzel, D. 827 Waizier, B. 324, 760, 1012 Walker, D. 31 White, J.L. 729 Vaicatitis, R. <		von Buseck, C.R 1078	Weitsman, Y
Uchiyamada, T		VonGlahn, U	Welbourn, D.B 568
Udwadia, F. .79 Weller, W.H. 239 Udwadia, F.E. .1022, 1067, 1174 W Wellford, L.C. .1703 Uffer, F. .77 Wells, R.A. .1229, 1382 Ugai, Y. .1507 Wells, R.M. .1506 Uginičius, P. .382 Waberski, A. .1819 Wells, W.R. .190 Ujihashi, S. .570 Wada, B.K. .4,634,895 Wen, Y. .655 Un, W.K. .1395 Wada, H. .962 Wendler, B.H. .594 Upton, R. .1273 Waggoner, S.A. .1008 Wester, J. .929 Wajcfeld, J. .977 Westcott, M.E. .1486 V Walden, H. .502 Westervelt, W.W. .803 Walker, B. .547, 1234 Westervelt, W.W. .803 Vaidya, N.G. .0011 Walker, N.D. .637 White, J.L. .722 Vaidya, P.G. .1870 Wallertowitz, H. .362 Whitham, E.M. .144, 1652 Vaipayee, S. .1471	Überall, H382, 1232	Voy, C 1184	Welbourne, E.R 1068
Udwadia, F.E. .1022, 1067, 1174 W Wellford, L.C. .1703 Uffer, F. .77 Wells, R.A. .1229, 1382 Ugai, Y. .1507 Wells, R.M. .1506 Uginičius, P. .382 Waberski, A. .1819 Wells, W.R. .19 Ujinashi, S. .570 Wada, B.K. .4,634,895 Wen, Y. .655 Un, W.K. .1395 Wada, H. .962 Wendler, B.H. .594 Upton, R. .1273 Wagoner, S.A. .1008 Wendoroff, B. .53 Wahl, F. .585 Wester, J. .929 Walden, H. .502 Westervelt, W.W. .1803 Walker, B. .547, 1234 Wetzel, D. .827 Vaidya, N.G. .1011 Walker, K.P. .1794 White, J.L. .729 Vaidya, P.G. .1870 Waller, N.D. .637 White, R.N. .658 Vajpayee, S. .1471 Waller, H .1548 Whitham, E.M. .144, 1652 Vajpayee, S.	Uchiyamada, T		Welch, C.R
Uffer, F.	Udwadia, F		Weller, W.H
Uffer, F. .77 Wells, R.A. 1229, 1382 Ugai, Y. .1507 Wells, R.W. .1506 Uginičius, P. .382 Waberski, A. .1819 Wells, W.R. .19 Ujihashi, S. .570 Wada, B.K. .4,634,895 Wen, Y. .655 Un, W.K. .1395 Wada, H. .962 Wendler, B.H. .594 Upton, R. .1273 Waggoner, S.A. .1008 Wendroff, B. .53 Walker, B. .585 Wester, J. .929 Walden, H. .502 Westervelt, W.W. .1803 Walker, D.O. .31 Whaley, P.W. .75 Vaicaitis, R. .324, 760, 1012 Walker, K.P. .1794 White, B.N. .658 Vaidya, N.G. .1001 Walker, N.D. .637 White, R.N. .658 Vaidya, P.G. .1870 Waller, N.D. .637 White, R.N. .658 Vaipyayee, S. .1471 Waller, H. .362 Whitman, E.M. .144, 1652 Vajpayee, S. .1471 Waller, M. .368 Whitman, E.M. .144,	Udwadia, F.E1022, 1067, 1174	W	Wellford, L.C
Uginičius, P. 382 Waberski, A. 1819 Wells, W.R. 19 Ujihashi, S. 570 Wada, B.K. 4, 634, 895 Wen, Y. 655 Un, W.K. 1395 Wada, H. 962 Wendler, B.H. 594 Upton, R. 1273 Waggoner, S.A. 1008 Wendroff, B. 53 Walker, R. 585 Westervelt, W.W. 1486 Walker, B. 547, 1234 Westervelt, W.W. 1803 Walker, B. 547, 1234 Wetzel, D. 827 Vaicaitis, R. 324, 760, 1012 Walker, K.P. 1794 White, J.L. 729 Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. 658 Vaipayee, S. 1471 Wallertowitz, H. 362 White, R.N. 658 Vajpayee, S. 1471 Waller, H 1548 Whitman, R.V. 1763 Valentin, R.A. 98 Wallrapp, O. 23 Widnall, S.E. 344 Van Blaricum, P.J.C. 432 Walter, M.J.	Uffer, F		Wells, R.A1229, 1382
Ujihashi, S. 570 Wada, B.K. 4,634,895 Wen, Y. 655 Un, W.K. 1395 Wada, H. 962 Wendler, B.H. 594 Upton, R. 1273 Waggoner, S.A. 1008 Wendroff, B. 53 Wahl, F. 585 Wesler, J. 929 Wajcfeld, J. 977 Westcott, M.E. 1486 Walker, B. 547, 1234 Wetzel, D. 827 Walker, B. 547, 1234 Wetzel, D. 827 Walker, D.Q. 31 Whaley, P.W. 75 Vaicaitis, R. 324, 760, 1012 Walker, K.P. 1794 White, J.L. 729 Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. 658 Vaidya, P.G. 1870 Wallentowitz, H. 362 Whitham, E.M. 144, 1652 Vajpayee, S. 1471 Waller, H 1548 Whitman, R.V. 1763 Vaicaya, P.G. 1870 Waller, H 1548 Whitman, R.V. 1763 Vane, J.C.	Ugai Y 1507		Wells RW 1506
Un, W.K. 1395 Wada, H. 962 Wendler, B.H. 594 Upton, R. 1273 Waggoner, S.A. 1008 Wendroff, B. 53 Wahl, F. 585 Wester, J. 929 Wajcfeld, J. 977 Westcott, M.E. 1486 V Walden, H. 502 Westervelt, W.W. 1803 Walker, B. 547, 1234 Wetzel, D. 827 Walker, D.Q. 31 Whaley, P.W. .75 Vaicaitis, R. 324, 760, 1012 Walker, K.P. 1794 White, J.L. .729 Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. .658 Vaidya, P.G. 1870 Wallentowitz, H. 362 Whitham, E.M. .144, 1652 Vajpayee, S. 1471 Waller, H 1548 Whitman, R.V. .1763 Valentin, R.A. .98 Wallrapp, O. 23 Widhall, S.E. .344 Van Blaricum, P.J.C. .432 Warter, M.J. .761 Wierwille, W.W. .67	Ogui, 1		***************************************
Upton, R. 1273 Waggoner, S.A. 1008 Wendroff, B. 53 Wahl, F. 585 Wesler, J. 929 Wajcfeld, J. 977 Westcott, M.E. 1486 V Walden, H. 502 Westervelt, W.W. 1803 Walker, B. .547, 1234 Wetzel, D. .827 Walker, D.Q. .31 Whaley, P.W. .75 Vaicaitis, R. 324, 760, 1012 Walker, K.P. 1794 White, J.L. .729 Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. .658 Vaidya, P.G. 1870 Waller, M.D. .637 White, R.N. .658 Vaidya, P.G. 1870 Waller, M.D. .362 Whitham, E.M. .144, 1652 Vajpayee, S. 1471 Waller, H .1548 Whitman, R.V. .1763 Valeya, S. 1471 Waller, M .1548 Whitman, R.V. .1763 Van Blaricum, P.J.C. 432 Walter, M.J. .61 Wierwille, W.W. .67		Waberski, A	
Vanl, F. 585 Wesler, J. 929 Wajcfeld, J. 977 Westcott, M.E. 1486 Valden, H. 502 Westcott, M.E. 1486 Walker, B. 547, 1234 Westcvelt, W.W. 1803 Walker, D.Q. 31 Whaley, P.W. .75 Vaicaitis, R. 324, 760, 1012 Walker, K.P. 1794 White, J.L. .729 Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. .658 Vaidya, P.G. 1870 Wallentowitz, H. .362 Whitham, E.M. .144, 1652 Vajpayee, S. 1471 Waller, H .1548 Whitman, R.V. .1763 Valentin, R.A. 98 Wallrapp, O. .23 Widnall, S.E. .344 Van Blaricum, P.J.C. .432 Walter, M.J. .761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandem, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van De Vegte, J. .1257 Wang, M.S. .380	Uginičius, P	Wada, B.K4, 634, 895	Wells, W.R19
VWajcfeld, J.977Westcott, M.E.1486VWalden, H.502Westervelt, W.W.1803Walker, B.547, 1234Wetzel, D.827Walker, D.Q.31Whaley, P.W75Vaicaitis, R.324, 760, 1012Walker, K.P.1794White, J.L729Vaidya, N.G.1001Walker, N.D.637White, R.N658Vaidya, P.G.1870Wallentowitz, H.362Whitman, E.M144, 1652Vajpayee, S.1471Waller, H1548Whitman, R.V1763Valentin, R.A98Wallrapp, O23Widnall, S.E344Van Blaricum, P.J.C432Walter, M.J761Wierwille, W.W67Vance, J.M.1358, 1754Wambsganss, M.W990Wierum, H1371Vandam, K721Wang, C.Y1672Wilby, J.F225, 652van den Bosch, J.W366Wang, H.C398Wild, R1155Van De Vegte, J1257Wang, J.C.F338Wild, R.E317Vandiver, J.K1064Wang, K.S1870Wiley, A828VanLaningham, F.L618Wang, T.G1545Wiley, J.C1380Van, W.P47Wang, T.G1699Wilgen, F.J491VanThiel, M197Wang, T.M1784Wilken, I.D436Varadan, T.K413, 1313,Wang, Y.S1384Wilkerson, J.B515 <th>Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395</th> <th>Wada, B.K4, 634, 895 Wada, H962</th> <th>Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594</th>	Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395	Wada, B.K4, 634, 895 Wada, H962	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594
V Walden, H. 502 Westervelt, W.W. 1803 Walker, B. 547, 1234 Wetzel, D. 827 Vaicaitis, R. 324, 760, 1012 Walker, K.P. 1794 White, J.L. 729 Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. 658 Vaidya, P.G. 1870 Wallentowitz, H. 362 Whitham, E.M. 144, 1652 Vajpayee, S. 1471 Waller, M.J. 1548 Whitman, R.V. 1763 Valentin, R.A. .98 Wallrapp, O. 23 Widnall, S.E. 344 Van Blaricum, P.J.C. .432 Walter, M.J. 761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. 1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828	Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395	Wada, B.K	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53
Walker, B.547, 1234Wetzel, D.827Vaicaltis, R.324, 760, 1012Walker, D.Q.31Whaley, P.W.75Vaidya, N.G.1001Walker, K.P.1794White, J.L.729Vaidya, P.G.1870Wallentowitz, H.362Whitham, E.M.144, 1652Vajpayee, S.1471Waller, H1548Whitman, R.V.1763Valentin, R.A.98Wallrapp, O.23Widnall, S.E.344Van Blaricum, P.J.C.432Walter, M.J.761Wierwille, W.W.67Vance, J.M.1358, 1754Wambsganss, M.W.990Wierum, H.1371Vandam, K.721Wang, C.Y.1672Wilby, J.F.225, 652van den Bosch, J.W.366Wang, H.C.398Wild, R.1155Van De Vegte, J.1257Wang, J.C.F.338Wild, R.E.317Vandiver, J.K.1064Wang, K.S.1870Wiley, A.828VanLaningham, F.L.618Wang, P.C.1545Wiley, J.C.1380Vann, W.P.47Wang, T.G.1699Wilgen, F.J.491VanThiel, M.197Wang, T.M.1784Wilken, I.D.436Varadan, T.K.413, 1313Wang, Y.S.1384Wilkerson, J.B.515	Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395	Wada, B.K	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929
Walker, D.Q .31 Whaley, P.W. .75 Vaicaitis, R. .324,760, 1012 Walker, K.P. .1794 White, J.L. .729 Vaidya, N.G. .1001 Walker, N.D. .637 White, R.N. .658 Vaidya, P.G. .1870 Wallentowitz, H. .362 Whitman, E.M. .144, 1652 Vajpayee, S. .1471 Waller, H .1548 Whitman, R.V. .1763 Valentin, R.A. .98 Wallrapp, O. .23 Widnall, S.E. .344 Van Blaricum, P.J.C. .432 Walter, M.J. .761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1156 Van De Vegte, J. .1257 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang,	Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486
Vaicaitis, R. 324,760, 1012 Walker, K.P. 1794 White, J.L. 729 Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. 658 Vaidya, P.G. 1870 Wallentowitz, H. 362 Whitham, E.M. 144, 1652 Vajpayee, S. 1471 Waller, H 1548 Whitman, R.V. 1763 Valentin, R.A. .98 Wallrapp, O. .23 Widnall, S.E. .344 Van Blaricum, P.J.C. .432 Walter, M.J. .761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, T.G. .1545 Wiley, J.C. .1380 Vann, W.P. <td>Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395 Upton, R. 1273</td> <td>Wada, B.K. .4,634,895 Wada, H. .962 Waggoner, S.A. .1008 Wahl, F. .585 Wajcfeld, J. .977 Walden, H. .502</td> <td>Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803</td>	Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395 Upton, R. 1273	Wada, B.K. .4,634,895 Wada, H. .962 Waggoner, S.A. .1008 Wahl, F. .585 Wajcfeld, J. .977 Walden, H. .502	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803
Vaidya, N.G. 1001 Walker, N.D. 637 White, R.N. 658 Vaidya, P.G. 1870 Wallentowitz, H. 362 Whitham, E.M. 144, 1652 Vajpayee, S. 1471 Waller, H 1548 Whitman, R.V. 1763 Valentin, R.A. .98 Wallrapp, O. .23 Widnall, S.E. .344 Van Blaricum, P.J.C. .432 Walter, M.J. .761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, J.C. .1380 Van, W.P. .47 Wang, T.G. .1545 Wiley, J.C. .1380 VanThiel, M. .197 Wang, T.M. .1784 Wilken, I.D. .436 Varadan, T.K. .	Uginičius, P. 382 Ujihashi, S. 570 Un, W.K. 1395 Upton, R. 1273	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827
Vaidya, P.G. 1870 Wallentowitz, H. 362 Whitham, E.M. 144, 1652 Vajpayee, S. 1471 Waller, H. 1548 Whitman, R.V. 1763 Valentin, R.A. .98 Wallrapp, O. .23 Widnall, S.E. .344 Van Blaricum, P.J.C. .432 Walter, M.J. .761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vanr, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75
Vajpayee, S. 1471 Waller, H. 1548 Whitman, R.V. 1763 Valentin, R.A. .98 Wallrapp, O. .23 Widnall, S.E. .344 Van Blaricum, P.J.C. .432 Walter, M.J. .761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilken, I.D. .436 Varadan, T.K. .413, 1313 Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729
Valentin, R.A. .98 Wallrapp, O. .23 Widnall, S.E. .344 Van Blaricum, P.J.C. .432 Walter, M.J. .761 Wierwille, W.W. .67 Vance, J.M. .1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilken, I.D. .436 Varadan, T.K. .413, 1313 Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658
Van Blaricum, P.J.C. 432 Walter, M.J. 761 Wierwille, W.W. .67 Vance, J.M. 1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilken, I.D. .436 Varadan, T.K. .413, 1313 Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652
Vance, J.M. 1358, 1754 Wambsganss, M.W. .990 Wierum, H. .1371 Vandam, K. .721 Wang, C.Y. .1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilker, I.D. .436 Varadan, T.K. .413, 1313 Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, H. 1548	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763
Vandam, K. .721 Wang, C.Y. 1672 Wilby, J.F. .225, 652 van den Bosch, J.W. .366 Wang, H.C. .398 Wild, R. .1155 Van De Vegte, J. .1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. .1064 Wang, K.S. .1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilker, I.D. .436 Varadan, T.K. .413, 1313 Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, H. 1548 Wallrapp, O. 23	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344
van den Bosch, J.W. 366 Wang, H.C. 398 Wild, R. 1155 Van De Vegte, J. 1257 Wang, J.C.F. 338 Wild, R.E. 317 Vandiver, J.K. 1064 Wang, K.S. 1870 Wiley, A. 828 VanLaningham, F.L. 618 Wang, P.C. 1545 Wiley, J.C. 1380 Vann, W.P. .47 Wang, T.G. 1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. 1784 Wilken, I.D. .436 Varadan, T.K. .413, 1313 Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, H. 1548 Wallrapp, O. 23 Walter, M.J. 761	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67
Van De Vegte, J. 1257 Wang, J.C.F. .338 Wild, R.E. .317 Vandiver, J.K. 1064 Wang, K.S. 1870 Wiley, A. .828 VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilken, I.D. .436 Varadan, T.K. .413, 1313 Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, H. 1548 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371
Vandiver, J.K. 1064 Wang, K.S. 1870 Wiley, A. 828 VanLaningham, F.L. 618 Wang, P.C. 1545 Wiley, J.C. 1380 Vann, W.P. .47 Wang, T.G. 1699 Wilgen, F.J. 491 VanThiel, M. .197 Wang, T.M. 1784 Wilken, I.D. 436 Varadan, T.K. .413, 1313 Wang, Y.S. 1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4, 634, 895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, H. 1548 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371 Wilby, J.F. .225, 652
VanLaningham, F.L. .618 Wang, P.C. .1545 Wiley, J.C. .1380 Vann, W.P. .47 Wang, T.G. .1699 Wilgen, F.J. .491 VanThiel, M. .197 Wang, T.M. .1784 Wilken, I.D. .436 Varadan, T.K. .413, 1313, Wang, Y.S. .1384 Wilkerson, J.B. .515	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672 Wang, H.C. 398	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371 Wilby, J.F. .225, 652 Wild, R. .1155
Vann, W.P.	Uginičius, P	Wada, B.K. 4, 634, 895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672 Wang, H.C. 398 Wang, J.C.F. 338	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371 Wilby, J.F. .225, 652 Wild, R. .1155 Wild, R.E. .317
VanThiel, M.	Uginičius, P	Wada, B.K. 4, 634, 895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672 Wang, H.C. 398 Wang, J.C.F. 338 Wang, K.S. 1870	Wells, W.R. 19 Wen, Y. 655 Wendler, B.H. 594 Wendroff, B. 53 Wesler, J. 929 Westcott, M.E. 1486 Westervelt, W.W. 1803 Wetzel, D. 827 Whaley, P.W. .75 White, J.L. 729 White, R.N. 658 Whitham, E.M. 144, 1652 Whitman, R.V. 1763 Widnall, S.E. 344 Wierwille, W.W. .67 Wierum, H. 1371 Wild, R. 1155 Wild, R. 1155 Wild, R.E. 317 Wiley, A. 828
Varadan, T.K 413, 1313, Wang, Y.S	Uginičius, P	Wada, B.K. 4, 634, 895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, H. 1548 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672 Wang, H.C. 398 Wang, J.C.F. 338 Wang, K.S. 1870 Wang, P.C. 1545	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371 Wilby, J.F. .225, 652 Wild, R. .1155 Wild, R.E. .317 Wiley, A. .828 Wiley, J.C. .1380
	Uginičius, P	Wada, B.K. 4, 634, 895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, M.J. 1548 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672 Wang, H.C. 398 Wang, J.C.F. 338 Wang, K.S. 1870 Wang, P.C. 1545 Wang, T.G. 1699	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371 Wilby, J.F. .225, 652 Wild, R. .1155 Wild, R.E. .317 Wiley, A. .828 Wiley, J.C. .1380 Wilgen, F.J. .491
1444, 1467 Warburgon, G.B	Uginičius, P	Wada, B.K. 4, 634, 895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, M.J. 1548 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672 Wang, H.C. 398 Wang, J.C.F. 338 Wang, K.S. 1870 Wang, P.C. 1545 Wang, T.G. 1699 Wang, T.M. 1784	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371 Wilby, J.F. .225, 652 Wild, R. .1155 Wild, R.E. .317 Wiley, A. .828 Wiley, J.C. .1380 Wilgen, F.J. .491 Wilken, I.D. .436
	Uginičius, P	Wada, B.K. 4,634,895 Wada, H. 962 Waggoner, S.A. 1008 Wahl, F. 585 Wajcfeld, J. 977 Walden, H. 502 Walker, B. 547, 1234 Walker, D.Q. 31 Walker, K.P. 1794 Walker, N.D. 637 Wallentowitz, H. 362 Waller, H. 1548 Wallrapp, O. 23 Walter, M.J. 761 Wambsganss, M.W. 990 Wang, C.Y. 1672 Wang, H.C. 398 Wang, J.C.F. 338 Wang, K.S. 1870 Wang, P.C. 1545 Wang, T.G. 1699 Wang, T.M. 1784 Wang, Y.S. 1384	Wells, W.R. .19 Wen, Y. .655 Wendler, B.H. .594 Wendroff, B. .53 Wesler, J. .929 Westcott, M.E. .1486 Westervelt, W.W. .1803 Wetzel, D. .827 Whaley, P.W. .75 White, J.L. .729 White, R.N. .658 Whitham, E.M. .144, 1652 Whitman, R.V. .1763 Widnall, S.E. .344 Wierwille, W.W. .67 Wierum, H. .1371 Wilby, J.F. .225, 652 Wild, R. .1155 Wild, R.E. .317 Wiley, A. .828 Wiley, J.C. .1380 Wilgen, F.J. .491 Wilkerson, J.B. .515

Williams, D.J. 987 Williams, H.E. 1731 Williams, J.E.F. 256 Williamson, R.K. 1053 Wilson, A.N. 588 Wilson, G.P. 719 Wilson, J. 1268 Wilson, T. 1485 Wilson, T.L. 645 Wineman, A.S. 396 Winemiller, J.R. 647 Winfrey, R.C. 508, 1065 Winkler, C.B. 177 Winney, P.E. 1438 Witczak, K.J. 1137 Witek, A. 601 Witham, C.R. 1 Wittig, L.E. 1764 Wittlin, G. 1725, 1726, 1854 Woan, CJ. 492, 1293 Wolf, CD. 562 Wolf, E.J. 1494 Wolf, J.P. 231, 1408 Wolf, F.H. 12 Wong, C. 386 Wong, H.L. 737 Wong, J.Y. 1185 Wood, L.A. 1343 Woodward, R.P. 604, 1666 Woolley, B.L. 1818	Yamada, G. 310 Yamada, H. 548 Yamada, M. 233 Yamaguchi, S. 1216 Yamakawa, H. 1443 Yamakawa, I. .76 Yamakawa, I. .76 Yamakoshi, K. .930 Yamamoto, T. .228 Yamane, J.R. .27 Yang, J.C.S. .928 Yang, T.Y. .696, 897, 959, 960 .940 Yanik, A.J. .1095 Yao, J.T.P. .642 Yashima, S. .1294 Yasuda, K. .228, 1251 Yavin, Y. .500 Yen, H.H. .609 Yeh, T.T. .296, 945 Yen, C.F. .1827 Yeow, K.W. .1240 Yerlici, V. .1746 Ying, S.P. .1042 Yoerkie, C.A. .701 Yonetsu, S. .743, 1179 Yorio, C.R. .1423 Yoshida, K. .1874 Yoshida, K. .1874 Young, G.E. .635 Young, M.E. <th>Zimmerman, R.M. 1049 Zimmermann, H. 454 Zinn, B. 1740 Ziv, A. 501 Zomotor, A. 889 Zorowski, C.F. 790 Zsolcsak, S.J. 903 Zuladzinski, G. 560</th>	Zimmerman, R.M. 1049 Zimmermann, H. 454 Zinn, B. 1740 Ziv, A. 501 Zomotor, A. 889 Zorowski, C.F. 790 Zsolcsak, S.J. 903 Zuladzinski, G. 560
Wu, J.J	Z	
Wu, R.W. 1455 Wu, S.M. 1503, 1504 Wuesthof, P. 1030 Wyn-Roberts, D. 1201 Wyskida, R.M. 152 Y Yaghmai, I. 414	Zagajeski, S.W. 1799 Zahradka, J. 755 Zaloumis, A. 973 Zaman, F.D. 944 Zahlein, H. 1667 Zell, J.B. 244 Ziebart, W. 399 Zienkiewicz, O.C. 1580 Zimmerman, Th. 77	

ANNUAL SUBJECT INDEX

	- A -	•			Acous 260	stic Measurii	ig m sti	ument 1264					
Absorbers (Equipment)			-	 -		stic Properti		1201					
				1839	7 KOU	suc rropertr		1554					
Absorbers (Materials) 132		326	327 159	no		stic Radiatio	'n						
152		320	347 13	90	930								
Accelerometers 671			54	48	Acous	stic Reflection 1392						1818	
			120									1010	
Acoustic Absorption					Acous	stic Resonan	ce		215	216	1307		
1302 1773	1634 16	635 1636	159	98 69					1815				
Acoustic Attenuation	L					stic Scatterir							
use Acoustic A	osorption					1231 382 1741		1734		1556	1387		
Acoustic Diffraction	214				Acous	stic Signatur	00						
A					1770	stic Digitatui	Co	1074		1846		468	
Acoustic Excitation 863	1484 1	145	10	08 929								1108 1258	
760			75 155	28 58	A	ai. Tashain							
A					Acous	stic Techniqu	953				1057		1699
Acoustic Fatigue	7	785									1277		
Acoustic Holography					Acous	stic Tests		1434		006	057	1160	
1280								1454		896 1426		1168	
Acoustic Impedance					Acous	stic Waves				,			
381	1234 11	135 856 1076	547 121 127						1385	1386			
Acoustic Insulation					Active	Absorption	1						
	674		32	28				1634					
Acoustic Liners					Active	Damping 742			595				
use Acoustic Li	nings				4				0,0				
Acoustic Linings					Active 1170	Flutter Cor 722		724	725	726	857	1488	
280 131 692 423 1301 1872	1164 11 1234	135	179) 8	Active	Isolation							
Acoustic Measurement					120110	2502421012	133	134				858	1169
262 363		406	97	78 1279				404					
Abstract Numbers: 1-194 195-370	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1	363 1	1364-15	16 15	517-1699	9 170	00-1896
Volume 10													
Issue: 1 2	3	4	5	6	7	8	9		10		11		12

Aerial 860	Rude	ders								Airer	aft Eq 71	uipmeı	nt Resp 403	onse					
Aerody	ynam 811 831	14 19 ic Ex	2 2 citatio			136	1197	1188 448 608		30 220 640 1010	521 1011	32	223 523 863 1013		35 1075 1635 1845		727	1168	219
			,	1464				298 478 628	1189	Aircra	ift Res	sponse	1853					1638 1848	
Aerody	nam	ic Re	sponse	:						7111010	111 140	ponse		1014					
•	ise			nic Stal	oility														
Aerody	nom	ic Sta	hility							Aircra	ft Sea	ts					457		
810 I			•	3		1896	1357		809										
										Airera	ft Tire	es							
Aeroela	ıstici 1761	ty													1835				
•	101									Aircra	ft Vib	ration							
Agricul 360	tural	Macl	inery						1869	20		722	143 723		725	726	1327		1479
Airborr	ne Eq	լսipm	ent Re	esponse						Aircra	ft Win	gs							
						1426				1170 1640	1641	1482				706 1326	927	448 458	459
Air Cor	npres ise		presso	re														1328	
			P. 02 00	••						Air Cu	shion	Landii	ng Syst	ems					
Air Con	ditio	ning	Equip	ment	1205													348	
790 Aircraft	ŧ				1395					Airfoil	s	442	443			536	857		459
450	451	452			75		27	8	449	810			***				1197		809
	571 591	732 782			135 335	446 456	137 337	138 638	779 859	Airfra	nes								
1480	661	1712	733	454	445	1406	447	678	1639								1757		
	721 731		1593	724 1084	455		1017	758 808		Airpor	• Nois								
	481			1464				000		-		e Airpor	ts						
				1844															
Aircraft	Eng	ines								Airpor 220	ts			204					
			893				1757		729										
				1674						Alignm	ent			1884		766	537		
Aircraft	Equ	ipmer	nt							Almonia	l		•	1001		100			
				1724	1015					Algorit	nms								1419
Abstract Numbers:		94	195-376	377-4	98 4	99-630	631-7	766 7	67-906	907-1057	1058-	1208	1209-13	63 13	364-151	6 151	7-1699	1700	0-1896
Volume 1 Issue:	U 1	1	2	3		4	5		6	7	8		9		10		11		12
			-							· · · · · · · · · · · · · · · · · · ·							<u> </u>		

Ammunition 683	3				Artillery Fire	55	56		
Amphibious Vehicles	3 _. 484				Asymmetry				1599
Amplification 72		35	٠		Automated Transportation 162 1182	Systems			
Amplitude Analysis 1823	3	101	5		Automobile Bodies				
Amplitude Data	3				1140		396 1116	397	
Analog Simulation	1184					174 175 364 885	176		1188
Anechoic Chambers	.	405	257	69	1353				•
Angular Vibration		75			Automobile Seat Belts		1096		
Anisotropic Properties use Anisotropy					Automobile Tires			437	438
Anisotropy		705			Axial Excitation 702 1443 1	304			
					A				
Ankles			10	18	Axisymmetric Vibrations			997	1329
Ankles Antennas 1281	964	965	10 527	18		- B -		997	1329
Antennas	mies	965 1655		18 1049	Balancing use Balancing Tecl Balancing Techniques			997	
Antennas 1281 Anthropomorphic Dum Approximate Methods	mies 234 1654	1655			Balancing use Balancing Tecl	hniques	1416 1 1586 1 1766	257	1329 489 1769
Antennas 1281 Anthropomorphic Dum	mies 234 1654 tion Me	1655			Balancing use Balancing Tecl Balancing Techniques 540 401 951 Ball Bearings	hniques	1416 1 1586 1	257	489
Antennas 1281 Anthropomorphic Dum Approximate Methods use Approxima	mies 234 1654 tion Me	1655	527		Balancing use Balancing Tecl Balancing Techniques 540 401 951 Ball Bearings	hniques	1416 1 1586 1	257	489 1769
Antennas 1281 Anthropomorphic Duma Approximate Methods use Approxima Approximation Methods	mies 234 1654 tion Me	1655	527 117 1367 47		Balancing use Balancing Tecl Balancing Techniques 540 401 951 Ball Bearings 1110	hniques	1416 1 1586 1 1766	257	489 1769
Antennas 1281 Anthropomorphic Dum Approximate Methods use Approxima Approximation Methods Arches 1800 981 283 Articulated Vehicles 180	mies 234 1654 tion Me	1655 thods	117 1367 47	1049	Balancing use Balancing Tech Balancing Techniques 540 401 951 Ball Bearings 1110 Barges 513	754 514	1416 1 1586 1 1766	257 587	489 1769 89 969
Antennas 1281 Anthropomorphic Dum Approximate Methods use Approxima Approximation Methods Arches 1800 981 283 Articulated Vehicles 180	mies 234 1654 tion Me	1655 thods	117 1367 47	1049	Balancing use Balancing Tech Balancing Techniques 540 401 951 Ball Bearings 1110 Barges 513 Bars 410 1121 402 1830	754 514	1416 1 1586 1 1766	257 587 87 247	489 1769 89 969

Beams 80 8	1 82	83	84	85	86	47	268	79	Blast	Loads			27		
100 41 420 47 690 71 830 96	1 412 1 872 1 962 1 1282	573 853 1123 1323	264 284 534 1124	265 435 555 855	266 516 686 1286	77 267 507	688 908 1288	269 829 979 1359		use Bla	Construction ast Resistant S	Structures			
920 129 1440 132 1600 144 1780 178	1 1442 1 1782	1443	1444	1215 1285	1336 1776	977 1287		1469 1829			Design ast Resistant S Structures	Structures			
1830										1021		1565 1705			
Bearings 113		273 1413			416		968 1448		Blast 1620	Response	96	4 965 1565	47 507		529 1549 1619
Bellows 1510									Boiler		72	1875			
Bells				1555					Bolot	in Method		1315			
Belt Drives			1894						Bond	Graphs use Bo	nd Graph Tec	hnique			
Bernoulli-I	Euler Mo l 1442								Bond	Graph Teo	chnique	635			
Bernoulli 7	heory						268		Bones	117	72				
Bibliograph 2: 92:	922		204	205	206 1546		1718	1719		•	uter Program)	ġ	926		
Bioenginee	ring l 1172						1018	1329	80	-	ition Effects	1445		308	
Biomechan	ics		194						Dound	iary Layer	Excitation				79
Blades 810 21		353 603	574	275	376 826	417	298 1788	299 1440	1700		Problems 383 583	18	356	108	
		1793			020		1100	,	Box B	eams	26	4			
Blast Effec	ts	1623				1827			Brakes	(Motion	Arresters) 122	4	1117		359
Blast Excit	ation 112				46				Brakin	g Effects 48	364	1		178	
Abstract Numbers: 1	-194 1	95-376	377-49	98 4	99-630	631-	766 7	67-906	907-1057	1058-1208		<u></u>	1517-1699		0-1896
Volume 10 Issue:	1	2	3		4	5	5	6	7	8	9	10	11		12
— — —				_											

Bridges 460 1331 530 1330	592 1332 1642					307		339	Cargo Sh Cavitatio		493						
Buckling	1822				276		408		Cavities	1006		1684				698	
Buildings										1232	2						
780 341	342	213	394	735	676	637	788	519	Cavity-C	ontaining	· Media						
461	1022		1024		1026		868	679	duvity	V11441111116	,cuiu				1387	1218	
1021		393	1484	1025	1336	1717	1558	929							1001	1410	
		693	1744	1245	1486	1747	1858	1649	Cavity R	esonator	s						
		863		1335	1646				520	1232			1845				
		1023		1405	1746												
		1043		1485	1856				Center L	ine Defle	ctions						
		1333		1645					1120								
		1643		1745													
	•								Ceramics	1							
Bumpers									2	41							
	322	323	854			207			•								
	922								Chain Dr								
_									1110 11	11	883		1515	1516			
Buses																	
	362	323							Chains								
												814			1207		
	····			C -													
			•	<u>. </u>			<u>.</u>		Chatter								
									1500	11 742			595		597		1179
Cable Cars										1502	773			1866	1867	1868	1499
		1203					88		Chimmon	_							
0.11									Chimney	s							959
Cables (Rop	es)	060		1 =0.5													939
		263		1785	966		88		Circuit B	nards							
		1723							Cheuit B	vaius					297		
Calibration															291		
	C-lik-								Circular (Cylinders							
use	Calibr	ating							Circular	ay inideis	1133			976			
C											1100			710			
Cams 1110	982	983							Circular I	Membran	ee						
1110	902	900							on ourse.				425				
Cantilever B	eame																
1290 1601		413	964	515	616	687	418	1249	Circular I	Plates							
12/0 1001	1482		1284	965	010		1308		80 3	11	583	584	705	1616	1817		
•		1283		1125			1778	2			703	704	1615				
							2					1614	,				
Cantilever Pl	lates																
1611			114			97			Circular I	Rings							
	1612		1824			687				852							
Caps (Suppo	rts)								Circular S	Shells							
			1324						570								
Abstract																	
Abstract Numbers: 1-1	94 1	95-376	377-49	98 4	99-630	631-	766 7	67-906	907-1057 10	58-1208	1209-1	363 1	364-15	16 15	17-1699	3 170	0-1896
			ψ., T	7		501			2000. 10		50 1	'	,0				
Volume 10										÷							
Issue:	1	2	3		4		5	6	7	8	9		10		11		12
						-											

Clearance Effects		Component Mode Ana	dysis 24	557
Closures		Component Mode Syn 1792	thesis 1374	199
Clutches 695 905 Coatings	906	Composite Materials 120 1821 1770		57 118 119 938 939 1458
1633 1833	1627	Composites 80	03 804	928
Codes (Standards)		110		1248
Coefficient of Friction 1503		Composite Structures 301 662	305 475	306 97 1796 1817
Coherence Techniques	1237	Compression Waves	3	
Collapse use Failure Analysis		Compressor Blades 90 1790	974 1295 1294	689
Collision Research (Aircraft) use Crash Research (Aircraft)		Compressor Impellers 890		
	206 207 398 1049 356 357 428 1099 396 397 588 1409 1096 1097 1048 1679 1656 1727 1098 1678 1728	Compressors 351 332 10 1591 352 602 692 1032 1872	3 1664 185 505	1257 608 1509
Collision Research (Railroad) 795	796 587 797		3 554	
Collision Research (Ships) 52		Computer Aided Techn 540 42 630 542 670 562	64 865 1 164 1414	637 669 909
Columns 1215		1660 1680	1534	1799
Columns (Supports)	276	Computer Programs 130 111 52 2 210 211 212 13	3 24 165	26 27 28 209 446 37 68 219
Combination Resonance	1517	580 301 342 21 600 511 472 30	34 385	516 147 138 489 646 647 218 529
	9-630 631-766 767-906 90	07-1057 1058-1208 1209	-1363 1364-1516	5 1517-1699 1700-1896
Volume 10 Issue: 1 2 3	4 5 6	7 8 9	10	11 12

Volume 10															
Abstract Numbers: 1-194	195	5-376	377-4	98 4	99-630	631	-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	170	0-189
661			1624	1035		807	658		Couple	d Systems	913				
Containment St	ructi														1469
16	72							529							1369
Containment									1250	,, 0,4	-0-0		2001		629
	•	493							Couple 930	d Response 91 872			1607	1608	419
Containers		402							С.	J D					
						1401		1007	1730	242	1400 100	- 107J			100
Construction In	dustr	y		,		1487		1559	Coulor 240	nb Friction	1253 186	A 1905	•		1659
				10.0				/			00				
			1394	1505 1675				1379 1859		ation Techni 1241	iques 63	4			
Construction E	quipn		1004	1				1050	<u> </u>						
16	42		1464			997		1619	160				177		43 87
Conical Shells	00		1464			00=		1610		ing Effects		*	·		
430										1782					
Conformal Map	ping								Corioli	s Forces					
use Ge	omet	ric E	ffects						960						
onfiguration E			ffa -1:						580					1438	143
	•				.10	10/1			Coolin	g Towers					
230 580		533	1694	45		357 1697		1799		- -	88	4			
Concretes									Coolin	g Systems					
60 61										-	and Coolin	g Systems			
Concrete Const	ructio	on							Coolin	g Fans					
1801										•	81	4	346		
1 51				1775	1656	397	1090	1003	Conve	yors					
Computerized S	imul	ation	ı	705	1656	107	1959	1659	1	use Contr	ol Equipm	ent			
			,						Contro	ol Systems				.*	
Computer Simu	latio	n			396						142				
										1421 1422	6	4	1297		149
							1818		Contro	l Equipmen	ıt				
							1718 1728	1739		1242					
		803						1729		22				•••	
1740 1731 16		623 693		1685 1725		1727		1629 1659		uum Mecha 1531 2	nics			688	
1730 1671 15			1724					1549			•				
1610 1611 13			1224			1657		1379	٠	1372					
1380 1551 10 1550 1601 13		643 693		1035 1075	1886	927 1017	498 648	779 1229	Contin	uous Param 572	eter Metho	d			
020 1381 7	82	513	374	645	1726	887	488	699							
780 781 5		373	tinued 274	625	926	747	398	649	Contin	uous Beams	1				180

Couplings 902 90	3 345	1138 279	Cylindrical Bodies use Cylinders
Crack Propagation 60			Cylindrical Shells 60 111 112 293 294 295 296 507 438 109 110 391 382 1823 1845 576 577 578 1149
Cracked Media 942	687	409	110 391 382 1823 1845 576 577 578 1149 200 701 702 1146 1147 1148 1459 570 851 1172 1826 1387 1288 1619 930 1311 1827 1618
Cranes (Hoists)	1337	1289	1310 1460
Crankshafts 1892			
Crash Research (Aircraf 1100 51 793		1408	Damage Prediction 1480 842 935
Crashworthiness 1100 1071 922 1473	1097	398 1099 1678	Dam Gates 121 122 123
Critical Speeds 620 641 12 880 1512 1050 1780	584 365 186 1437 754 766		Damped Structures 1570 1571 232 924 925 1209 1700 852 Dampers
Curved Beams			531 Damping
Curve Fitting	556 196		990 892 224 1856 1878 239 1250 1362 1364 569 1472
Curved Beams 410	1445		Damping Coefficients 950 273 1174 415 1127 148 559 1130 1345 318
•	ck Insulation		1028 1058 1128 1568
Cutting 1502	1867	599 1319	Damping Effects 110 61 772 373 374 266 499
Cylinders 200 201 1412 93 700 561 1622 1623	435 1796 277 975 287		1210 1251 1604 1580 Damping Materials
940 931 1620 1621 1631	1355 977 1 1797	1528	1411
1741 1761			Damping Values 19 321 1639
	377-498 499-630 631-7	766 767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10 Issue: 1 2	3 4 5	6	7 8 9 10 11 12

Issue: 1 2 3	4	5	6	7 8 9 10 11 12
Abstract Numbers: 1-194 195-376 377-4 Volume 10	98 499-630	631-766 7	67-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
1184		188		Dynamic Loads use Dynamic Excitation
1680 611 13 14	915 1046	138	479	B
Digital Simulation	AND	_	. –	Dynamic Excitation 820
1160 751 613 884		477 1878 1087		1324 115 699
Diesel Engines 1160 751 613 884	955 476	<i>477</i> 1070		Dynamic Buckling
902				Bynamic Balancing 667
Diaphragm Couplings				Dynamic Balancing
		1768	1107	Dynamic Antiresonant Vibration Isolators 284 1027
		1418 1588		Dynamia Antipagonant Vihyatian Italian
		1258		891 772
1590 1111 1063 1414		1767 1108	669	Dynamic Analysis
1110 401 952 253 554 1260 1071 1112 553 624		957 538 1417 668	379 539	1870 1451 1392
	1415 1416	247 248	249	1450 1301 1302 1303 1634 1676
Diagnostic Techniques				280 21 282 53 94 525 376 1137 978 1299 1300 281 692 423 1134 1135 746 1307 1798
1262		537		Ducts 280 21 282 53 94 525 376 1137 978 1299
250 1261 252 1263		407	1259	
Diagnostic Instrumentation				Drop Tests (Impact Tests) 683
		1057		Dron Torte (Impact Tarks)
Detection				use Drills/Ships
1842	1875	1837		Drillships
890 1831 1202 1293	1475 1696			570
480 351 492 493 1534 630 891 562 983 1674	355 566 405 906	407 568 1107 828	469 909	Donnell Theory
Design Techniques	255 566	407 E60	460	584
and Data I tooloomg				574 417 1318
Data Reduction use Data Processing				Disks
				use Disks
62 1413 672				Discs
Data Processing				1214
	1186			Discrete Fourier Transform
Data Presentation	****			1142
11				Discontinuity-Containing Media 942 943 295
Data Dependent Systems				
1401 1402 1403				542 65 505
1580 121 122 123			739	42 813 914 15 16 137
Dams				Digital Techniques

Dyna	mic Pl	asticit	tv																
•	711		•	1124		996 1566		98	979						- E -				
										Earth	ı Hand	lling Eq	uipme	ent					
Dynai	mic Pr	-	ies 2 633	914	1205	1046	1017		1139			1492					1177		1859
Dynai	mic R	elaxat	ion							Earth	ı Mode	els							
)					845													1338	3
Dynai	nic Re	espons	se ·								_	Damag	ge	1004					200
	741		513	164	625	446	447	448	619	390	391	342		1334	•	1746	1217 1227		389
1200			783			1286		1018	1029								122.		
1490	1671		1243 1383		765				1319	Earth	quake	Predic 1722	tion						
				984						Earth	miake	Resista	ant De	sion					
_											use			Ų.	ant St	ructure	8		
Dynan 720		-		1594	125	1106	1617	1040	760				•						
730 910	911	1612	1053	1524	575	1196	1017	1828	769			Resista							
710		1012	•		313			1020		230			393			986			659
Dynan	nic Sti	ffness	3							340		1222 1402	693				1227		709
•		1472			1585					960	1221	1402		864	985 1705		1627 1717		1039
										700			1333	1404	1703		1747		
-		uctur	al Anal	•															
770	461 771		1673	1064	1055	26 1686	77 767	998 1198		Earth	quake	Respon	nse						
	111			1004		1000	917	1190		230		682		1744		656		1648	
							/1.			•	1401	1532	623 843		1645				959
Dynam	nie Str	uctur	al Resp	onse									1183						
1	use	Dyna	mic Re	sponse									1403						
Dunan	.:. c												1533						
Dynam 1160	ne sy	ntnesi	s						899				1563						
									0,,	Fauthe									
Dynam 1710	•	stems 632	3				7	378	1709	Eartho	quakes	i	933				657		
										Eigeny	zalue P	roblem	ıs						
Dynam										430	561	502		994	1365	926		688	1059
770	771		1043 1453		1035	1686	197	678		780						1366		778	
		1412	1593					1048		1530									
					·					Eigenv	alues								
Dynam	ic Vib	ration	ı Absor 853	ption ((Equip						use	Eigenv	alue P	roblen	ns				
			1003	114		76													
Dynam	a-mat		1003							Elastic	Analy 581	ysis				1376			
Dynam	omen	15			1595					F1	**								
										Elastic 1440	471		1123	1614			117 1707	438	829
Abstract																			
Abstract Numbers	: 1-19	94 1	95-376	377-49	18 49	99-630	631-7	766 76	67-906	907-1057	1058-	1208 1	1209-13	363 1	364-151	6 151	17-1699	1700	0-1896
Volume	10																		
Issue:	1		2	3		4	5		6	7	8		9		10		11		12

Elastic Media 41 22 1573 1574	1246		Electrohydraulic Shakers 42 73 65 202
Elastic-Plastic Properties		269	Electrohydraulic Systems 954
Elastic Properties 940 962 573 165	25 1247	1298 1318	Electro-Internal Combustion Engines 484
1071 1572	25 1706 57 87	648 919 1218	
1121 1812 Elasticity Theory			Electromagnetic Shakers 202 73
1321			Electromagnetic Shielding 1427 1398
Elastodynamic Response 712			Electronic Instrumentation 72 1427
Elastohydrodynamic Properties		1489	1432 Enclosures
Elastomeric Bearings	1786		790 1164 855 717 1325 1427 1735
Elastomeric Dampers	55		Energy Absorbers use Energy Absorption
Elastomers			6)
1472 1404 140 1812 1814)5	1398 239 1568	Energy Absorption 1100 1001 322 323 854 716 587 558 1099 922 713 1124 1546 657 588
Elasto-Plastic Properties 980 2 84	1 5		1153 1404 1048 1473
Electric Automobiles	1097	,	Energy Dissipation 240 1895
Electric Generators use Electric Power Plants			Energy Methods 912 1827
Electric Power Plants 960 1561	656 897	1508 1648	Engine Mufflers 1475 1277
Electrical		1698	Engine Noise 30 751 752 223 154 355 1676 257 718 330 1162 613 475 517 1478
Electrodynamic Shakers	66		520 1013 1085 1087 1848 680 1113 1675 1163
Abstract Numbers: 1-194 195-376 377-498	499-630 63	1-766 767-90	6 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10			
<u>Issue: 1 2 3</u>	4	5 6	7 8 9 10 11 12

Engine Vibration 613 Engines	475	1047 1878	Explosion Effects 980 236 1040	
872		139 1879	Explosions 936	
Environmental Effects			- F -	
1772 193				
Environment Simulation	16		Failure Analysis 1090 1211 92 893	1348
EPSOLA (Computer Progr	eam)		702 953 973	
Er so Er (Compatet 1106:	,	1718		
Emustions of Mation			Fan Blades use Fans	
Equations of Motion 690 1693	1775 556	158 9 99	ubv I uits	
1360 1783		1199	Fans 350 1791 602 543 604 225 606 6	17 348 349
Equipment Mounts			470 1871 1382 1013 744 605 746 12	
1470 71	715	1837		47 1348 1229
671			1870 1872 1794 1505 1506 15 1665 1666	07 1349
Equipment Response 541 542	655 1426	1837 48	Fast Fourier Transform	
011 012	000 1120	100.	761 42 1193 954 546 10	47
Equivalent Sound Levels		1697	1274	
1082 1433		1637	Fast Fourier Transformation	
Error Analysis			use Fast Fourier Transform	
40 321	1076		Fatigue Life	
1220				47 58 399
Exhaust Noise			1132 456	1459
		1879		1759
Exhaust Systems	1235		Fatigue (Materials) 1760	
Experimental Data		•	Fatigue Strength	
230 901 52 793	384 225 1186		use Fatigue Life	
	434 565 1666	797 658 1149	Fatima Tasta	
	524 805 634 1655	1097 1568 1249 1608 1629	Fatigue Tests 571 1015 1596	
1011	1755	1628	941	
	1885	1858	TOTAL COLUMN	
Experimental Possita			Fiber Composites 953	57 939
Experimental Results use Experimental	Data		1153	,, ,,,
Evaluation Detaction (No1	oar)		Finite Difference Method	
Explosion Detection (Nucleon use Nuclear Explo	sion Detection		1626	
Abstract Numbers: 1-194 195-376 :		631-766 767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1	699 1700-1896
Volume 10				
Issue: 1 2	3 4	5 6	7 8 9 10 11	12

Finite Difference Technique	Floors
280 294 845 746 197 108 269 1825 1678 459	1322 1486 128
1010 107	Flow-Induced Excitation
Finite Difference Theory	use Fluid-Induced Excitation
use Finite Difference Technique	
E'a ta D'alanna Malad	Flow-Induced Vibration
Finite Displacement Method 873	use Fluid-Induced Excitation
	Fluid Drives
Finite Element Technique	1206
270 131 432 303 504 95 126 47 508 769	
320 441 862 1073 694 705 336 437 708 829	Fluid-Filled Containers
490 731 1132 1363 944 1065 426 927 768 849	100 1141 1542 1576 1577 428 1149
850 851 1282 1353 1064 1215 696 1527 848 909	110 1826 578
970 1161 1442 1703 1284 1465 996 1617 898 1299 1020 1321 1622 1554 1525 1066 1707 998 1439	700 1578 1460
1320 1441 1584 1575 1116 1218 1529	1400
1370 1461 1685 1526 1458 1669	Fluid-Film Bearings
1490 1501 1785 1606 1528	970 1191 1193 1194 415 416 558 559
1550 1671 1646 1708	1130 1884 1195
1580 1721 1696	1885
1620 1886	
The Court Marie	Fluid Film Damping
Finite Strip Method 1642 1644	1751 805
1042 1044	Fluid Hammer
Flexibility Methods	698
1	
, , , , , , , , , , , , , , , , , , ,	Fluid-Induced Excitation
Flexible Couplings	200 111 302 243 454 185 286 287 278 109 810 201 352 453 1584 945 296 577 808 589
513 514 285	1350 561 452 763 1624 975 536 807 828 689
815	1460 811 842 1033 1664 1575 696 947 948 949
Flexible Foundation	1810 831 1412 1813 1795 846 1107 1278 1459
1643 188 1509	841 1762 1875 946 1137 1308 1579
1010	931 1812 976 1577 1558 1689
Flexible Rotors	1761 1106 1578
951 485 367	1811 1456 1618
1051 1587	1576
TO 1 3 7/4 (*	Fluid-Induced Vibrations
Flexural Vibrations 120 1621 962 303 124 435 576 117 278 419	use Fluid-Induced Excitation
120 1021 902 503 124 453 570 117 278 419 1060 1822 573 264 585 686 417 308 1309	Fluid Mechanics
1600 963 1304 705 1306 1467 708	1703
1790 1123 1314 1315 1836 958	1100
1384 1355	Flutter
	470 591 722 833 444 95 286 377 8 279
Floating Bodies	910 691 762 1173 734 445 696 907 298 299
use Floating Structures	862 1483 1294 725 726 927 628 809
Flanking Campana	1482 1683 1256 1147 808 859
Floating Structures 531 812 1283 764	1522 1793 1296 1197 1479 1712 1326 1327
	1712 1327
Abstract	0074057 4050 4000 4000 4000 4004 4500 4500
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10	
Issue: 1 2 3 4 5 6	7 8 9 10 11 12

Foams 1631 177	3			1009	Free Vibration 760 631 1122 1143 264	195 1346 847 268	309
	o .			1007	1700 1611 1283 424	835 1826 1317 848	
Forced Vibration 1210 581 632		165 1286	5 2	28 849	1444	1888	
631 852		1865		58 1089	Freight Cars	1107 1107 070	1650
1571 882 962				318 1199 708 1209	611 473 1494 1181 1873 1864		1059
1212			18	88 1369			
				1809	Frequency 1291		
Forging Machinery 1471		1495			E A1		
		1493			Frequency Analyzers 650 1771 1274	816	
Fossil Power Plants			897		Frequency Equation		
Franklik and					. , .	87	419
Foundations		666	5 737 8	68 139	Frequency Response Method		
				1599	130 1454 170		
Four Bar Mechanisms				1649	1500	1108 1118	
rour dar mechanisms		1305			Friction		
Fourier Analysis					901		
1263	3 44				Fuel Storage Tanks		
Fourier Series					ruei Storage Taliks	1328	•
			557		Fuel Tanks		
Fourier Techniques					- 407 - 411110	1855	
use Fourier An	alysis				Fundamental Frequency		
Fourier Tranformation					120 1821 582 704 1800	1316	119
170 1231 82	914 1214				1000		
					Fundamental Mode 1303		
Fourier Transforms use Fourier Tra	ınsforma	tion			1000		
Fracture Properties		•					
830					•	G -	
1770					Galerkin Method	•	
Framed Structures					1300	1365	299
562 563			657 12	28 1799	Can Pagringa		
		835 1646			Gas Dearings		
1532 693 1023	1644	835 1046	1647		Gas Bearings 271 272	486 1127 1128	
1532 693	1644	835 1046			-	486 1127 1128	
1532 693 1023 1533 Frames	1644			0.50	271 272 971 Gas Turbine Engines	486 1127 1128	
1532 693 1023 1533	1644	835 1646		979	271 272 971	486 1127 1128	
1532 693 1023 1533 Frames 980	1644 424	836	1647	979	271 272 971 Gas Turbine Engines 223 154 1754	486 1127 1128 364-1516 1517-1699 1700-1	1896
1532 693 1023 1533 Frames 980	1644 424 1304	836	1647	 	271 272 971 Gas Turbine Engines 223 154 1754		1896

Gas Turbines					Ground	d Vehicles					
•				8 1029	480	221 362	173	164 465	67	18	439
			150	8		1662		174	327		479
C D								384	, 1557	918	639
Gear Boxes		866				1 7711					
		000			Ground	d Vibration			1405	,	
Gear Drives									1487		
1110	1804				Guard	Rails					
					530		1843		356 357	1098	
Gears									716		
10 1031 1112 1413		65 5 66	567 56						1546		
1801 1452	694		837 83	8							
1802					Guided	l Missiles					
										628	
Geometric Effects				000							
1650 1651				399	Guidev				•		
1740				429		161					
Coometrie Imperfection	Effects					1351					
Geometric Imperfection 701 982	1324				C	!- Pec					
1802	1024				Gyrose 1050	opic Effects					
1002					1030						
Girders											
370 1831	264										
								- H -			
Gliders											
	734				Half Pl	ane					
								1585			
Graphic Methods				_							
			46	8	Half-Sp						
C.11. (D C.11.)						962		1615	1247	1298	
Grids (Beam Grids) 783										1318	
, 100					TT 11.			`\			
Grinding Machinery					Hamut	onian Princi 631	iple				
	1504					031					
2000	1001				Hamme	are					
Grinding (Material Remo	oval)					.16		1495			
743				1179				1170			
1503					Handbo	ooks					
					υ	ise Manua	ds - Han	dbooks			
Ground Effect Machines											
1360 1361 172	484		877 74	8	Harden	ed Installati	ons				
1861					50	61		54		48	49
Cround Moster					••						
Ground Motion 791 1742	74		100	8 1749		ed Structure					
171 1144	1764		102	O 1147	U	ise Hardei	nea Inst	allations			
	2.01				U	.:. D.J \	Made - 1				
Ground Shock					riarmo	nic Balance l	Method		1517		
1601	1244	46							1017		
Abstract				-							
Abstract Numbers: 1-194 195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-136	3 1364-15	316 1517·169	9 1700	0-1896
		555									
Volume 10											
Issue: 1 2	3	4	5	6	7	8	9	10	<u>11</u>		12

Harmonic Excit: 1820 271 63 1311		974	1695 1865	1816		228 938 1088 1318		20 140	-	ìbration					
Harmonic Respo	onse 92 833								141 821	142 1	153	395			869 1529
Harmonic Waves 100 1230	803 1703						939	260		esonato	rs		547	•	
Head (Anatomy)	143					428	1329	Hemi	spherica	d Shells 792					
H . P .	593							High	Frequen	ıcies				1798	
Heat Exchangers 290 561 84 990 991 1810 1811			1285 1815 1875	946 1456	947 1307			High	Frequen	icy Exci	tation			938	
Heat Shields								High	Frequen	•	nance ' 253	Technique			669
760 Heaving 1360								High	Frequen	cy Resp 942					
Helical Gears								High !	Speed R		193				
180 Helical Springs	2				1607	1608		High :	Speed T	ransport 222	tation				
1320 Helicopter Blader			585 1625	1626					Speed Ti 161 1		tation S 23 16 33 18	64	876 167		159 879
use Rota Helicopter Engine	ary Wing es	; s						Highw	ay Barri	iers					
g		24 834	345	1696					·			1	1546		
Helicopter Noise 1650 1651 462	2 343	34	25		37					sportati 7					
652					1637			Hitche)rawbar:	3				
Helicopter Rotor: 820 141 212 1260 421 1551		344	275 515	536 1606	1027		239 1429	Hoists					866 1337		
Helicopter Seats								Hole-C	Containi	ng Medi			306 316		
	195-376	377-49	18 49	99-630	631-7	66 76	7-906	907-1057	1058-12	08 120	9-1363	1364-1516	1517-1699	1700	1896
Volume 10 Issue: 1	2	3		4	5		6	7	8		9	10	11	1	2

Issue:	1	2	3		4	5	5	6	7	8		9	10		11	,	12
Abstract Numbers: Volume 10		95-376	377-49	98 49	99-630	631-	766 7	67-906	907-1057	1058-1	1208	1209-1363	1364-151	16 15	17-1699	1700)-1896
Hydrauli	c Valves						948		Indus 1560	trial Fa 1381		s 1393	1535	1476 1536		328 1008	
Hydrauli 720	c Systems														1011		
	_			1170					Induc	tion M	otors	•			1677		
Hydrauli	c Servome	chanis		1795					_								
77 1 10									Inclus	ions		1233					
	1072		1474	915 1165													
Hydrauli	ic Equipme		1463						Impel 890	lers							
440			1494						.								
	ic Dampers	3	1404									•	795	356 796	797		
		473							Impa	ct Tests	5		# 0.5	0=1			
Hunting	Motion	<i># 1</i> 70								use	ımpac	ct Tests					
			,				1558		Impa	ct Testi		. 4 T 4 .		,			
1860 14	191 361	1653		1395			1078							1406			
	341 1652	463		235 1175	1176 1656	217	798 918		-					86			779
740	171 1342 331 1562	143 183	134 144	145	146	67	218		Impa	ct Shoc	k						
Human l	Response												•			1808	
us		s (Biol	ogical))						661	312	83	1805		1407	1148 1298	
Human (Organs									711	152	153 8	84 85	1796	1247		1679
us	se Head	(Anato	omy)						Impa	ct Resp	onse ((Mechanica	l)				
Human i	Head								=:[L.y.			1203					
		1343							Impa	ct Load	l Predi	iction					
Human i	Hand								*mpa	use		k Absorber	s				
370									Imna	ct Dam	nore					_	
Hulls													-1				
Hovercra us		nd Effe	ect Ma	chines													
**	٠.							/				1323	003			1838	619 1569
Housing	s					1767		1529	Hyste	eretic E	Dampir	ng 663	665			060	610
390									11yul	ostatic	Dilve	•	905				
Hospital	ls								Hydr	ostatic	Driva	•					
	omb Struct 571	tures	1844			137			Hydr	ofoil C 371	raft						
			024						1580	ı	1752						
		303	544 824		216	1117		359	170		812		785				
												citation					

Industrial Noise use Industrial Facilities and Noise	Generation	Interaction: Vehicle-Terrain 460 361 182 885 319 1680
Inertial Forces		1000
1782		Interaction: Wheel-Pavement
Inflatable Structures		481
812 1283		Interface: Solid-Fluid
T.C. C. CC M		1669
Influence Coefficient Matrix use Influence Coefficient Method		Tutaufanamataua
		Interferometers 544 1117
Instrumentation	4-0	824
870	678	Y
Instrumentation Response		Interior Noise 652 1163 1635 1636 639
785		1012 1845
Instruments		V
use Instrumentation		Intermittent Motion 1807
		1501
Interaction: Rail-Wheel 750 611 222 1873 1034 165 166	160 : 160	Internal Damping
472 1874 103 106		900 664 1468
	1729	Internal Pressure
Internation Dates States		98
Interaction: Rotor-Stator 1052	617	Isolators
		1404 147
Interaction: Soil-Foundation	500	1657
	738	Lecturany
Interaction: Soil-Structures		Isotropy 181 182 113 1354 776
	737 868	1133
660 791 1583 1174 950 1581 1763	1227	Iteration
		1521 1704 845 267
Interaction: Solid-Fluid		
931 1584		
Interaction: Structure-Fluid		-J-
1611 792 1813 764 945 236 1672 944 1145		LA Francisco
1672 944 1145 1255	1797 1669	Jet Engines 784
Interaction: Structure-Foundation 1244	1579	Jet Noise 1740 1241 522 523 524 35 1477 1738 29
1274	1319	823 784 1737 1389
Interaction: Structure-Medium		1739
1245	107	Injuta (Iunationa)
Interaction: Vehicle-Guideway 1662 23 875		Joints (Junctions) 240 1453 1805 1139 1249
Abstract Numbers: 1-194 195-376 377-498 499-630	631-766 767-906 9	07-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10		
Issue: 1 2 3 4	5 6	7 8 9 10 11 12

Journal Bea 270 271		41 48	5	367 487 1127			d Damping 532		534	106		
		- L -					301 1102 1391	803 1103	804	126 266 1466	, 1	118 1248
Laminates use	Layered Mat	erials				Least S	Squares Met	hod			907	
Landing			1406		779	_	ov's Metho use Lyap	d unov Fu	nctions			
Landing Fie use	lds Aircraft Land	ding Areas				Limiti	ng Friction					159
Landing Gea	ar 1153	101	5 1016				Analysis use Linea	r Theori	ies			
Landing Impuse	pact Landing and	Impact Sh	ock				Systems 1571	1	1704	5 6		
Landing Sho use	ock Landing and	Impact Sh	ock			1700 1720						
Landing Sim use	nulation Landing and	Simulation	n			Linear	Theories	1693		,	177	
Laplace Tra	nsformation 82 1213			15-	48 1729	Linkag	es 511			1806		569
Large Ampli	itudes 1613					_	Filled Cont use Fluid		Containers			
Lasers 71							Propellants 1691			626 1576	1577	
Lateral Resp 1880	oonse 1182		176		169	Locom	otives 1562		171	5		
Lateral Vibr 880	ation		156	18	88	Longit	udinal Vibra	ntion 1133	58	5		
Launchers		89	5			Loss F	actor	503				
Launching				16	88	Low F	requencies				967	
Launching F 1200	Response					Lubric	ation		224 151	5		
Abstract Numbers: 1-	194 195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-13	63 1364-	1516 1	517-1699	1700-1896
Volume 10												

Lumped Mass Method use Lumped Parameter Method	Magnetic Bearings 1604 1605	
Lumped Parameter Method 1372 1743 1054 1774	Magnetic Properties 629 870 76	
1774	Magnetohydrodynamics	
Lyapunov Method 1062	487	
1002	Manifolds	
- M -	1278	
	Manuals and Handbooks	
Machine Diagnostics	1551 917	1239
use Diagnostic Techniques	Marine Propellers	
Machine Elements	973	
use Machinery Components	Masonry	
Machine Foundations	1221 1627	
630 622 736 867	Mass Coefficients	
Machine Noise	301	
use Machinery Noise	Mass Matrices	
Machinery	563	19
512 755 1417 1	Mass-Beam Systems	
Machinery Components 1661 1072	78 Mass Transportation	
Machinery Foundations	748	
use Machine Foundations	Material Damping	
Machinery Noise	535 1166 1757	
466 1086	329 Materials 1842	
1736	Materials Handling Equipment	
Machinery Vibration	346	
1251 518 Machine Tools	Mathematical Modeling use Mathematical Models	
600 11 742 773 1344 595 466 1867 598	599 M. Alexandria N. J.	
1500 151 873 1804 596 858 1		129
601 1498 1 741 1868	180 131 212 273 104 635 196 357 198	149
1501		179 729
Machining		829
597	1370 971 572 873 634 1055 376 747 438 1400 1131 602 913 824 1655 396 857 658 1	939 210
	1400 1131 002 913 024 1033 390 037 038 1	
Abstract Numbers: 1-194 195-376 377-498 499-630 631-766 767	7-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-	1896
Volume 10		_
<u>Issue: 1 2 3 4 5</u>	6 7 8 9 10 11 12	

Matha	matia	al Mad	lata (Ca	ntinue	A)					Maahr		Duona	utio.				
	1181			1054		496	867	688	1509	Mecha	anicai	Prope	rties		126		
				1224			1497		1669						120		
				1354			1737		1679	Mecha	anical	Reliab	ility				
1890			1873			746			1709		use		bility				
,-		1332		1694		1066			1889			200120	,				
		1532		1754		1106		1238		Mecha	anical	Shake	rs				
				1774		1456		1388				202					
				1874				1648									
								1738		Mech	anical	Syster	ne				
Mathe	ematic	al Proc	rammi	inσ								872		1865	6		388
			,						909	1000		912		1000	Ū		1178
									, . ,		/	/12					1110
Matrix	x Meti	nods								Mecha	anical	Telem	etrv				
		1322	563					128	19			1592					
												10,2					
Maxi-	Eleme	nt Tec	hnique	!						Mecha	nism	R					
						106				1730				1065		1297	1139
														2000		/-	
Maxin	num R	lespon	se .							Memb	ranes						
		•	1243											705	1306		
															1556		
Measu	iremer	ıt İnsti	ument	8													
	use	Meas	ıring İı	nstrum	ents					Metal	Work	ing					
			Ū									1502			1866		1319
Measu	ıremer	ıt Tecl	nigues	3													
90	221	262	363	74	75	386	1557	538	1279	Metho	d of	Charac	teristics				
680	551	822	553	914	1435	1716		1278		1320					746		
1430	1081	1382	1433	1034	1595	1736									1626		
1500				1594	1715	1846											
										Metho	d of	Initial	Functions				
Мооп	ring T	netmin	ontatio	\n											116		
weasu	use		entatio	าง าstrum	anta												
	use	Mease	n mig m	istium	CHES					Metho	d of	Steepe	st Descent				
											use	Steep	est Descent	t Method	l		
		nstrum										_					
70	1591			1114		546	167			Metho	d of S	Superp	osition				
		1592	1413	1274		816		1208					993			1317	
						1266		1268									
					1275		1267	1428		Metho	d of \	Weight	ed Residual	ls			
					1715				1269								1299
	_	echniq	•	. m 1						Micro	phone	8					
	use	Meast	ıremen	t Tech	nique	3											1269
M L -	1	A .J : A.															
Mecha	inicai .	302	iance							Milita	ry Fac	ilities					
		302								340							
Mecha	mical l	Deivor															
Mecua	unicar	Drives		1894						Mindli	in The	eory					
				1074													1818
Mecha	mical l	[mpad	nce							3.51	· ·						
	1071	anpeu		1514	1345					Mines	(Urdr	iance)					
	1011		000	1014	1949												1549
Abstrac	t																
Numbe		194 1	95-376	377-4	98 4	99-630	631	766 7	767-906	907-1057	1058	-1208	1209-1363	1364-15	16 15	17-1699	1700-189
Volume	: 10																
Issue:		1	2	3		4		5	6	7	8	3	9	10		11	12

	-																		
Abstract Numbers Volume 1		94 1	95-376	377-4	98 4	199-630	631	766 7	67-906	907-1057 10)58-12	208 1	209-136	33 13	64-151	6 151	7-1699	9 1700	0-1896
Model A	Adjusti	ment	Techn	ique				168		, and the second		12						58 768 1548 1838	39
			1643 1813		1465 1785				1609	Multidegr	ee of		dom Sy	/stems					
990	VU I					1036			1019	Multi-Bea	ım Sy	stems	93						
320 780 1	421· 061		373 563	504 1794	125 515	296 706	437 707	1438	429 729										
310	61 1	1312	263	374	105		137	438	189		51 41		1	004		856		718	
Mode S	hapes									Mufflers	31		1	004		956		710	
	771									110	01 1	104							
Modal 7	rests 681	772						1118			21 1 81 1								
34.137	r									1780 144	41	412		JTT		886	501	578	
	ļ	1742			645	646 1116	1877			Moving L 1440	oads 81	82		844		266	307	88	
Modal S	•				(4 =		10												
		232		1844								872 472				826			
vuul l		102		1124		296	137		189	Mounting	gs								
Modal i	Damni	ing			•							872	903				1497		
viiii '	ontit		qu	1774						Motors									
Modal (Contro	al Ter	hnian	n.							1	682						1118	889 1189
J				1014		1506			1889	Motor Ve								1110	000
	651 1171	1512		974 1074		1336 1376	1397	1548	1229 1829				•	1004					
820	341	102		924	1375	1146	1377	1228	629	Motor V	ehicle	e Engi		1534					
Modal 380	Analy: 281		1193	894	925	336	777	758	379										.47
M. 1 1	A 1									Motorcy:	cles 71								129
MODIII	iy met	nou				366													
Mobilit	ty Mat	hod								Motion I	Limit	ıng St	op		1865				
50		4012	1020			1056		40		11 m									
Missile:		1079	1623			16		48		Monte C	arlo l	Metho	d			1706	1217		
				1244	•			828											
Missile	Silos			1044				000		Modulus	of E	lastici	ity				887		
_						866				us	se l	Model	Testin	g					
Mining	Equip	pmen	t							Model T			_						
	1901				1213	,	1777		1779							1276			1149 1349
Minim	um We 1501	eight	Design		1215		1 777	908	909				200	484		1036			859
		392								3	371		223 483	354 444		936 946	497	1168	239 609
148 188 1111	ax Tec									Model T	estin	g							

Multis 1020	story l 781	Buildii 342		864	865	1836	127	1538	229	Noise 1160			•	ntinued	d) 1715	436		1428	184
		1322	2	1334 1644			1647 1857		1799		1241	1382 1732				546 1266			185
Music	al Inst	rumei	nts								1851	1852				1716 1736			
					215	216 1126			549	•• .									
						1120				Noise	Meter		d Leve	l Mete	rs				
Mykle	estad M		d																
	411									Noise	(Sour	nd)	1653	-					
					N ·					Noise	Dand:								
										- Noise 610		1732	1083			1006	1737	1238	219
NAST	ran	(Com	puter P	rogran	ns)					840							1847	1738	94
	1611		643	644		646				1080									1239
					1685		927	1718											1379 1739
Natur	al Fre	quenc	ies			.,													185
310	61	12			15	106	137	418	189	Noise	Propa	gation							
320 490	101 411	512 1462			105 125	296 306	267 437	438 1778	429 569						1085	1676			
780		1622			215	686		1788	729	Noise	Redu	ction							
1190		1892		1144	305	706	1287		829	220	21		333	324	355	326	327	328	329
1290				1284	515		1437		1019	330	331					466	387	718	
1310	1521			1794 1844	556 1445		1777		1339 1609	720 750	351 1161		1163 1223	674 744		476 586		948 1008	
	1001		1010	1011	1465				1779	1010			1223			606		1068	719
					1785					1030				1164		806		1168	749
N 7 1	G1 ·									1160				1474		816		1478	759
Naval	Ships			1514						1180				1714			1007	1508	
				1011						1840	1011	1012 1042	1009			1166 1206			1069 1539
Noise	Barrie	rs								1870		1052				1396			1559
1240			1773		325	1006						1162			1235	1476	1237		1869
		1832	1843									1302				1516			
Noise	Contr	ol										1352 1842			1505 1515	1536 1666	1537		
	use	Noise	Redu	ction								1862			1535	1000	•		
N 7 .	_											1872			1675				
Noise 840	Gener 1031	ation 192	343	224	225	1306	347	328	689						1845				
1870		222	543		1235		427	388	869	Noise	Sourc	e Ident	tificati	on					
	1511				1236	1506	567	518	969	3.5250	751	612	33	34	25	1086	1237		1389
		1562			1395		617		1429			652	1433	814	385				
		1682		1394	1909		1117 1347	638 728						884	605				
							1507			Noise	Tolera	nce							
													463	464					
Noise				604	EAE	24	0177	610	690	** -									
350 680	221 1011		1713 1733				817 1557		639 1079	Nonde	estruct use			tive Te	sts				
Abstrac Number	rs: 1-1	94 1	95-376	377-4	98 4	99-630	631-	766 7	67-906	907-1057						16 15	17-1699	170	0-1896
Volume		۰				500	301			22. 100/	. 500	. ===	,_50 1	'			1000	,,	000
ssue:		1	2	3		4	5 8		6	7	. 8		9		10		11		12

Nondestructive 1681	Tests			886	1387 1597		3	Nucl 1400	ear Power Pi 135:	ants (C 2 1183		ed)	1876			1259 1399
Nonlinear Anal																
use No	onlinear T	Theorie	s					Nucl	ear Reactor	Compo	nents					
Nonlinear Dam	nina							1670	111 1672	2 1673				1617		1459
1090	Ping			1756					1671		1624			1667		1669 1809
20,0																1009
Nonlinear Progr 17								Nucle 170	ear Reactor 6 882		nment					
Nonlinear Resp	onse							Nucle	ear Reactors							
1320 1041	1313	;		1816		1518	1469	11del	231			945	1036	1037	1668	
	1613								661			1035	1000	1877	1000	
									881							
Nonlinear Sprin	ıgs															
		1704						Nucle	ear Reactor S	Safety						
Naulineau Susta															28	
Nonlinear Syste 1090 1091		1104					39	No. al-								
1070 1071	1213						1519	Nucle 50	ar Weapons							49
							,	50								47
Nonlinear Theo	ries							Nucle	ar Weapons	Effects	3					
510	413		115		1327	8	579		•	1623				1567		
1370	633			1016		1648										
1520	1523		1695			1678			rical Analys							
Normal Density	Function	ne						500	501 502 1661	1703			1626		1458	499
Normal Delisity	1063						1519	1060	1001					1367		769 1609
							/	1640								1789
Normal Modes								1670								1.07
	72	994		1706		648		1740								
651			1375		777	1338		1830								
1291																
Nozzles																
- · · · - · · · · · · · · · · · · · · ·				1236							• (0 -				
										_						
Nuclear Explosion	on Dama	ge						Off-H	ighway Vehi	cles						1060
50							49									1869
Nuclear Explosi	on Effect	te.						Off-Sh	ore Structu	res						
1281	on Brice		935			48	1629		1632		764			1107	1198	1579
							1749		1762		1064					
											1694					
Nuclear Fuel Ele								011 711								
1670 1041 88	32						1669		lm Bearings		1004					
1671									1751		1884					
Nuclear Power P 1040 104	lants 2 1043	1044	1455	916	937	698	1039	Optica 90	ıl Methods							
Abstract Numbers: 1-194	195-376	377-4	98 4	99-630	631-	766 7	67-906	907-1057	1058-1208	1209-1	363 1	364-151	6 151	17-1699	1700	-1896
Volume 10																
Issue: 1	2	3		4		5	6	7	8	9		10		11	,	12
								··········								

Optimization 770 771 772 1443 1220 1061 1522 1863 1821 1702	1804 1215 1446 1586		Parameter Identification Technique (Continued) 1581 1192 644 1425 1176 1867 1868 1219 1372 1712
Optimum Control Theory 1170 1182	7	7	Parametric Excitation 1600 1054 1785 1517 409
Optimum Deisgn 1501 1821	1705	529 1119	Parametric Resonance
Organs (Biological) 1490 1171 1461	194	1489	Parametric Response 350 431 774 1695 1336 1524
Orthotropic Plates 1642			Parametric Vibration 510 1072 1603 1226 1457 920
Orthotropism 992 113	· 1466	119	Passenger Vehicles 172 1163 888
Oscillation 1640 371 442 443		288 289 458	Pavements 1681 614 886 887 1697
Oscillators 40 1212 500	1104 1364	499	Pendulums 1072 274
Overhead Cranes			Penetration 59
	. P .		Periodic Excitation 1621 1104 1125 226 39 1801
Packaging Materials 152 153 Panel-Cavity Response	1345 245	878	Periodic Response 270 1051 1253 174 875 786 38 1089 1751 1513 1865 1356 1088 1801 1813 1806 1178 1836 1518 1708 1838 1838
Panels 760 571 1102 243 1310 673	324 95 96 674 286 696	97	Periodic Structures 1531 555 1397 1228
Parachutes	794		Perturbation Theory 500 3 4 705 1816 847 229 1523 634 1397 1703 984
Parameter Identification ' • 1371 1022	Technique 184 615 636	337 168 19	Phase Data
	377-498 499-630	6 31-766 767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10 Issue: 1 2	3 4	5 6	7 8 9 10 11 12

Piezoelectricity 241 1172	Pneumatic Shakers 202 73
Pile Driving	Pneumatic Springs 1863
Pile Foundations 950	Pneumatic Tools 1432 1004 226
Pile Structures 1762	Pogo Oscillation use Pogo Effect
Pipeline Transportation 1454	Point Source Excitation 1541
Pipelines 1f . 0 291 103 1454 985 986	Poisson's Ratio 1781 1782
Pipes (Tubes) 100 1141 102 573 104 427 98 920 1392 697 1308 1460 987	Polyurethane Resins 322 1102
Piping Systems 101 843 1094 655 986 1037 198 99 1601 1033 985 698 1809	Porous Materials 1572 1234 Power Plants (Facilities)
1455 988 Pistons 381 474 1808	use Electric Power Plants Power Spectra 1351 732
Plain Bearings	Power Transmission Belts 900 901
Plastic Properties 1750	Power Transmission Systems 1110 1152 1363 1204 1696 1207 898 279 1804
Plates 120 121 122 113 114 115 306 117 118 119 300 301 302 203 304 305 706 297 238 299 430 711 432 303 704 575 846 307 298 579 580 1321 872 703 844 845 996 507 708 1549	Prediction Techniques 193 1856 1896
830 1391 992 833 1384 855 1316 707 908 1819 920 1142 1824 925 1466 847 1468 1829 1550 1315 1556 1467 1818	Pressure Gages 1114
1820 1465 1566 1707 1735	Pressure Vessels 1346 198
Pneumatic Equipment 1839	Prestressed Structures 402
Pneumatic Machine Drives 1660	Printing 1355
Abstract Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 Volume 10	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Issue: 1 2 3 4 5 6	7 8 9 10 11 12

Probability Theory 400 1211 1090	1216		1819	Railroad Cars 160 1181 163 1864 165 156 157 148 639 880 1873 879 1180 1659
Propeller Blades 691 973	826			Railroad Tracks 471 155 827 879
Propeller Induced Excitat	tion 1684		,	Railroad Trains
Propellers 492 543 1293	744			10 222 158 472 Railroad Vehicles use Railroad Trains
Propulsion Systems 1841	•	1847	729 1699	Railroads 166
Protective Shelters 782	1244 1565	1567		Rails use Railroad Tracks
Pulleys 901				Railway Vehicles use Railroad Trains
Pulse Excitation 1750 13 593 703	1504 1425	1367	979	Random Decrement Technique 208 Random Excitation 40 111 1092 1093 654 465 1216 1447 208 79
Pumps 1030 1031 1032 63 1590 1033	254 1496 874	347 747	609	150 941 1242 1213 885 1090 1091 1782 1243 1781
	1474	1257		Random Response 1614 336 38
	- Q -	· · · · · · · · · · · · · · · · · · ·		Random Vibration 992 243 227 58 1519 1063
Quasi-Moment Dampers 742				Rayleigh-Ritz Method 832 1315 1338
	- R -			Rayleigh Waves 677
Radio Telemetry	825			Reciprocating Engines 1001
Rail Transportation 610 750	876	878	3 719 749 879	Recording Instruments 1270 Rectangular Bars 87
	377-498 499-630	631-766	767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10 issue: 1 2	3 4	5	6	7 8 9 10 11 12

Rectangular Bodies 1761						Respo	onse Sp	pectra				18	37	789
Rectangular Membra	nes 98	4				Rever	beratio	on Cha	ımbers					
581 1822 13	993 994 313 1144 513 1314	4 42	16 1317 26	308 848 1458	;	Revie 200 510 920	201 511	202 642 1072		224 12		776	07 19 50 91	8 489
Re-entry Vehicles					1619		1541 1721			13	765		148	8 919
Regulations 1561 Reid Springs 632	,		1537 1717	1068	1069 1539	740	Dynam 801 1861	802	1	224	375] 385] 155		318 356 638 798 918	8 879 8 8
	93 43 4 23 13 34		77	658	709	Rigid :	Finite 601	Eleme	nt Techr	ique			1658	
Reinforced Structures					959	Rings		312 1472	433	124 1	25	88	37	
Reliability 20 8	73 1564	1545				Ritz M	lethod							
1480 Resonance Tests				1438		Ritz-G	alerkir		od 1643					
Resonant Bar Techniq use Resonanc		chnique		1100		Road I			183 13	854 8	85			
Resonant Frequencies									ynamics Jynamics					
-	13 1384		5 1047 5 1437	758	1439	Rock I	Orills		10	04				٠
Resonant Response 190 981 860 1590	834	1695 216 766		78	409	Rods 920 1820				12	15		958	
1870		1000	1377			Roller			1.600			170	-	
Resonators	1384						1111		1603			178	7	
	. 1004					Rolling	Fricti	on						89
Abstract Numbers: 1-194 195-3	376 377-4	198 499-63	0 631-	766 7	67-906	907-1057	1058-1	208	1209-1363	1364	-1516	1517-16	599 170	00-1896
Issue: 1 2	3	4	5	i	6	7	8		9	10	0	11		12

Rotary Compressors	607	Runways 1681 886
Rotary Inertia Effects use Rotatory Inertia Effects		
·		-8-
Rotary Presses	1306	
		Safety Belts use Seat Belts
Rotary Wings 590 1651 515	E26	use Seat Deits
	1606	Safety Restraint Systems
D		1095 1409
Rotating Structures 832 1053 684 575	1257 958 1259	Saint Venant's Principle
952 1263 1284	1201)00 120)	1625
1262 1513		Sand
Rotatory Inertia Effects		59
	686 578	Sandwich Laminates
570 1462 1784 1825		use Sandwich Structures
1892 1794		
Rotor-Bearing Systems		Sandwich Panels use Panels or Sandwich Structures
951 892 1193 184 485 1191 1192 1753 1194 1195 1	486 187 368 369 1196 367 489	use I aliels of Sanuwich Structures
1512 1883 1884 1885 1		Sandwich Structures
	1586 1887	571 82 324 435
	1886	SAP (Computer Programs) 782
Rotor Blades 690 811 422 274 615 1	1296	
Rotor Blades (Rotary Wings)	.=,0	Satellite Antennas use Spacecraft Antennas
use Rotary Wings		Satellites
Rotor Blades (Turbomachinery)		770 771 772 1055 626
421		1072
Rotor-Induced Vibration		Saws
	37	1540 88 3 1449
Rotors (Machine Elements)		Scaling
•	186 187 368 369	800 881 43 1514 676 798 509
490 691 1592 893 874 365	366 667 488 619	820 1593 1276 759 799
590 891 1892 1683 1664 615 620 1521 1834 685	616 1257 618 1699 1357 958 1889	1429
890 1891 1665	1358	0.1.(0.
1050	1888	Seals (Stoppers) 620
1190		
Runway Roughness		Seat Belts 921 1048
1014	138	741 1040
Abstract Numbers: 1-194 195-376 377-498 499	9-630 631-766 767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10		
Issue: 1 2 3	4 5 6	7 8 9 10 11 12

Secondary Waves 1582 1233	124	Shafts (Machine Elements) 345
Seismic Design 390 291 1022 393 790 391 1222 1023		Shakers 202 1533 66 258 1419
	1044 1025 986 1538 1149 1094 1335 1336 1399 1174 1405 1876 1799	Shear Strength 317
Seismic Excitation 660 791 1332 393	1745 654 655 1036 737 658 79	Shells 920 1321 572 1624 575 947 108 699 1000 1461 1542 1794 925 428 999
700 1043	1584 1828 709 1744 1649	1550 1824 998 1309 1308 1788
Seismic Response 1400 231 232 1323 1610 541 792 1743 1670 881	1644 1245 1026 697 1858 229 1455 897 339 1647 609 1877 649	Shells of Revolution 170
Seismic Response Spectra	789	Ship Anchors 372
341 42 Seismic Waves	u	Shipboard Equipment Response 1245 506
41 1722 1543 Self-Excited Vibrations	1544 1225	Ship Hulls 1362 1684 1685 189
	1884 185 756 1137 598 89 685 1866 1868 1359 755	Ship Noise 589
Semitrailers	1105	Ship Structural Components 625
150 180	1185 179	Shipboard Equipment Response
Series (Mathematical) 1503	·	Shipping Containers 683 1657
Servomechanisms	595	Ships 1281 494 495 1406 757 758 209
Shaft Couplings	904 815	624 775 917 1198 1199 Shock Absorbers
Shafts 1120 491 552 433 1072 553 1152 603	554 365 186 187 538 1119 684 685 1356 1437 1358 1599 1834 925 1436	1630 1471 1184 826 588
1892	1195 1665	Shock Absorption 1831 1153
Abstract Numbers: 1-194 195-376 Volume 10	377-498 499-630 631-766 767-906 9	007-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Issue: 1 2	3 4 5 6	7 8 9 10 11 12

Shock Isolation		•		48	•	Missiles) use Missi	ile Silos			
Shock Isolators	594				Simula	tion 821 1742			116 607	178 779
Shock Loads use Shock Excit						941 1531	933 1563		657	318 1419 1688
	ation				SINGE	R (Compu	ter Program))		
Shock Measurement use Measuremen	ıt Tachniqu	es and S	Shock Re	gnonse						1718
use measuremen	it Techniqu	cs and t	SHOCK IC	sponse	Single	Degree of l	Freedom Sys	tems		
Shock Resistant Design	1514		14	08	St)	1092		465		1838
Shock Response					Single-	Plane Balar 401	ncing			
1000 1101 43		506	1797	999						
643	794 1564				Sinuso 300	idal Excita	tion			
Shock Response Spectra					Skew I	Plates				
42	44			739		1642	2 1143			
Shock Tests					Skin-S	tringer Met	hod			
	1424 55		2	58				265		
	1425	•			Slamm 370	ing				
Shock Tubes					310					
				259	Slider	Crank Mecl	hanism			000
Shock Wave Attenuation										839
			2	38	Sliding	Friction	1874	1		
Shock Wave Propagation							10.	•		
1320 53	934 1115	1246	1247 174	18	Sliding	Power Col				
1410 1103 1430							1874	I		
					Sloshin					
Shock Waves 971	395		237		1690	1691 1692	2	15	576 1577	1578 1689
711	070	•	201		Soils					
Shrouds	004 100					1582	2			1339
1792 1663	834 1895)			Solid P	ropellant B	Rocket Engin	es		
Shuttles (Spacecraft)						191				
760 763					C 1	Da				
Signal Processing Techniq					Sonic I	300m 21	1853 1084	1		
•	•					Attenuatio	n			
Signatures			158	18	1	1541		325		1798
Abstract			100				· · · · · · · · · · · · · · · · · · ·		·	
Abstract Numbers: 1-194 195-376	377-498	499-630	631-766	767-906	907-1057	1058-1208	1209-1363	1364-1516	1517-1699	9 1700-1896
Volume 10										
Issue: 1 2	3	4	5	6	7	8	9	10	11	12

Sound Generation 1303	Spacecraft Equipment Response 1101 1693
Sound Insulation use · Acoustic Insulation	Spacecraft Launching 1101
Sound Level Meters 1772 817 1428 819 1267	Space Shuttles 761 192 373 374 896 337 1688 759 762 874 497 1202 1687
Sound Measurement 653 1435 819	Space Stations
Sound Pressure Levels 1381	Spectral Analysis use Spectrum Analysis
Sound Propagation 1450 281 94 1136 1387 1301 1134 1451 1254 1734	Spectral Energy Distribution Technique 181 813 954 1216 1107 1351 1873 1781
Sound Scattering 1142 1077	Spectrum Analysis 1093 914 1176 1597 248 1589 1744 1776 1368
Sound Transmission 1300 574 295 376 528 1299 784 1635 526 1735 1466 1636	Spectrum Analyzers 1261 1272 1273 248 Spheres
Sound Transmission Loss 721 1832 423 674 1325 1391 673 1833	932 Spherical Cavities 1233
Sound Waves 1230 931 932 383 995 107 928 989 1231 423 1218 1553	Spherical Shells 850 1462 593 996 107 1329 1150 1463 1731
Spacecraft 190 191 772 1053 894 895 16 1577 1578 1689 770 771 1202 1593 1054 1775 1576 1687 1200 1201 1692 1774 1686	Spring Constants 321 273 314 559 1154 Spring-Mass Systems
1690 1691 Spacecraft Antennas	use Mass-Spring Systems
627	Spring Method 1763
Spacecraft Components 1510	Springs (Elastic) 1151 313 1405
	07-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10	7 8 9 10 11 12

Spur Gears 1802	Steepest Descent Method
Squeeze Film Bearings 1028 1129 1128	Steering Effects 480 482 173 364 439 1880
Squeeze Film Dampers 1051 1152 1753 754 368 369 1891 1752 1754 488	Steering Gear 162 Step Functions
Stability 1720 2 1523 474 155 157 478 489 1882 1753 485 487 599 1185	5 Stick-Slip Response
Stability Analysis use Stability	Stiffened Panels 1140 1609
Stability Methods 912 1062	Stiffened Plates 1312 783 307 309 1467 849
Standards 640 1713 1266 1267 638 639	Stiffened Shells 1827 Stiffened Structures
Standards and Codes 20 671 1042 1223 864 865 916 1547 1538 781 1222 1373 1714 1535 1536 1413 1715 1716	Stiffness
Statistical Analysis 1410 54 565 1706 1368	1131 1498 1801 Stiffness Coefficients
1265 Statistical Energy Methods	950 301 1174 415 887 148 429 1130 1345 1127 318 1128
503 775 1369	1568
Steady State Excitation use Periodic Excitation	Stiffness Methods 461 1322 437 128 19
Steady-State Response use Periodic Response	Stochastic Processes 150 773 1226 757 768 9 1093
Steam Generators use Boilers	Storage Tanks 700 391 1692 1657 1328
Steam Turbines 1350 92 603 825 417 1509	Stored Response Modeling 1711
Steels 1532 1533 1645 1646 1647	Strings 1060 961 1126 967 1446 1447
Abstract Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 Volume 10	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Issue: 1 2 3 4 5 6	7 8 9 10 11 12

Structural Components use Structural M	Members			Surges 1032
Structural Elements use Structural M	Members			Surveys use Reviews
Structural Members 920 571 872 1633 1830 711 1411 1661	1834 435 516 665 675 925	787 1628	1829	Suspended Structures 1723 244 Suspension Bridges 862 1173 1019 1483
Structural Response 1750	86	27	789	Suspension Systems (Missiles) 496
Structural Synthesis 420 Subharmonic Oscillations	1804 s	1407 1058 1887	839 1789	Suspension Systems (Vehicles) 130 321 482 133 364 1155 1156 877 148 149 150 1151 1492 163 1224 1157 748 879 360 313 1494 1158 1159 1493 1864 1658 1169 1863 1659
Submarines	1514			Symposia
Submerged Structures 210 561 792 1463 1000 1611	944 975 236 1145	107 1528 1077 1618 1797	999	use Proceedings System Identification 193 18
Substructure Coupling use Component	Mode Synthesis			System Identification Technique 590 1371 642 1533 594 17 1488 1219 1220 1711 1532 1067
Subway Cars 1840				-Т-
Subway Railways		587		Takeoff 138 779
SUPERSCEPTRE (Comp	uter Program)	1718		Tanker Ships 495
Supersonic Frequencies	1306	728		Tanks (Containers) 626 1149
Supports 101	1285	697		Taxiing Effects
Surface Effect Machines 371				Temperature Effects (Excitation) use Thermal Excitation
Surface Roughness 181 182 183	1354 166	167	169	Test Data use Experimental Data
Abstract Numbers: 1-194 195-376 Volume 10	377-498 499-630	631-766 76	67-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Issue: 1 2	3 4	5	6	7 8 9 10 11 12

Test Equipment and Instrumentation 1420 1421 402 33 64 255 957			Thickness Effects use Geometric Effects
1422 73 404 815 1417 1602 1423 814 1425 1424			Thrust Bearings 558
Test Facilities 821 672 543 404 255 256 67	258	259	Tilting Pad Bearings 1882 1883 1196
673 674 675 406 923 676 956	318	1039	Time-Dependent Excitation 1781 1286
Test Fixtures use Test Facilities			Time Domain Method
Test Instrumentation use Test Equipment and Instrumentation Test Models			Timoshenko Theory 420 1282 1783 414 1346 268 829 1440 1784 1818 1789 1780
Test Stands	1098	339 509	Tire Characteristics 130 861 482 183 174 586 318 129 1002 364 478 439
955 Testing Apparatus use Test Equipment and Instrumentation			Tires 1002 314 315 316 317 438 319 1662 1224 436 437
Testing Equipment use Test Equipment and Instrumentation			Tools 1860
Testing Instrumentation use Test Equipment and Instrumentation			Torpedos 16
Testing Machines use Test Equipment and Instrumentation			Torque 1591 866
Testing Techniques 71 1432 33 434 825 856 657 681 1602 73 1434 1095 1596 1047			Torsional Excitation 1826 Torsional Response
1431 1712 823 1654 1277 1043 1844 Textile Spindles	1118		940 402 1744 366 1497 1298 489 1892 766 1646
1862 Thermal Excitation			Torsional Vibration 1600 151 12 553 124 435 866 1287 538 419
627 1147	288		871 942 903 264 585 1836 1878 429 1521 1262 943 554 1665 1888 1569 1204 1294
Thermoviscoelasticity Theory	1708		1814 1824
Abstract Numbers: 1-194 195-376 377-498 499-630 631 Volume 10	-766 76	67-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
	5	6	7 8 9 10 11 12

		3							8		9						
Abstract Numbers: 1-1 Volume 10	94 195-376	377-49	98 49	9-630	631-	766 7	67-906	907-1057	1058-	1208	1209-13	63 13	364-151	6 15	17-1699	1700	1-1896
	lity Transmissivi	ty						560						···			
				1806				Turbin 420		les 92			825			,	1789
		1194		1526			1889										
			1525				1129								1487		
1830	,,0			666			999	Lume	15						1057		
1570	993	114			1527	700	889	Tunne	la								
1 ransient Re 1150	983	104	175	116	1037	908	629			1632				1830	1837	-	
Transient Re	anonse							Tuned	Dam					1006	1007		
380 311								ar -	~								
Transient Ex	ccitation														1457		
								1810							1307		
1830 101		1834	105		187			990		842					947	_00	98
Transfer Mat	trix Method							290	841	572	1813	1814	1815	1456	287	288	28
201		1114			407			Tubes									
Transducers 261		1114			407					1202							
On								Trusse	s								
use	Railroad Tra	ains															
Trains															1187		
									1511				1110	1100	1157	1100	
		244				498			1081	012	919		1155 1175		177 477	178 1158	
Traffic Sign	Structures							Truck	s 361	672	313		1155	476	177	179	
				1396			1719	Tr	_								
				1276		1238	1239						955				
1240	1732 1733				1167			Truck	Tires								
	1082 753	464	385		1007												
Traffic Nois													1675				
								Truck	Engir	ies							
	592	614					1019					エ・フザ					
Traffic Indu	iced Vibratio	ns								1402		1784 1794	1825				
1911									1291	312 1462			1285	686		578	
150 1511			1182	1156				Trans			Deform					pr mr.C.	
Tractors			1105	1157						 -							
ш.	V2								use		sportati	on or	Transp	ortati	on Vel	nicles	
Tracking Fi	lters 62							Trans	portat	ion Sy	stems						
an	14										683				1657		
	1662							Trans	portat	ion Ef					1657		
	612							m									
Tracked Vel	hicles							800	801	802	}						
	1122				047	1458	1439	Trans	forma	tion							
Towers	1100					1400	1400						1205				
						558	•				1723		395				15
	tems					358		Trans	missic	n Syst							
Towed Syst																	
use Towed Syst	Towed Syst							1070				1044		1106			

Turbine Components 1510 1512	874			•	618		Underwater	Pipelines	1454					4
Turbine Engines 602 Turbines			1766		1478	1769	Underwater 210 1741 260	Sound	1254		526	527	108	
331	354	825		1257		1509	1390							
							Underwater	Structures						
Turbofan Engines 752			1046					138	3					
102			1666				Urban Noise	•						
								46	384			387		1079
Turbofans		1045						173	3 1734					
Turbomachinery									-	v -				
540 621 622	574	805		607		539								
630 641 1032			736 766				Valves							
1191 1592			1896				840	292	1474	505 1795	1236			609 949
Turbomachinery Blades							Variable Cro	es Section						
91 1132 833		1895			418		490		3 964		576	847	418	1119
					1788		1120		3 1144			1137		
Turbulence									3 1444		1136			
1811 732						689		114	3		1436 1616			
		U -					Variable Mat	terial Prope	rties					
														1599
Ultrasonic Tests use Testing Tec				٦			Variable Spe	ed Drives						1599 899
use Testing Tec	hnique			쇻										
use Testing Tec Unbalanced Mass Respon 190 621 892	hnique 1se	s 1195	766	187			Variable Spe Variational N 430 851				416		1338	899
use Testing Tec Unbalanced Mass Respon	hnique 1se	8	766				Variational N				416		1338	899
use Testing Tec Unbalanced Mass Respon 190 621 892 641	hnique 1se	s 1195	766				Variational N 430 851			765	416		1338	899
use Testing Tec Unbalanced Mass Respon 190 621 892 641 1051 1891	hnique nse 754	s 1195	766				Variational I 430 851 V-Belts	Methods		765	416		1338	899
use Testing Tec Unbalanced Mass Respon 190 621 892 641 1051	hnique nse 754	s 1195	766 936				Variational N 430 851	Methods		765 1835	416		1338	899
use Testing Tec Unbalanced Mass Respon 190 621 892 641 1051 1891 Underground Explosions	hnique nse 754	s 1195					Variational M 430 851 V-Belts Vehicle Whe	Methods els	974	1835			1338	899
Unbalanced Mass Responsible 190 621 892 641 1051 1891 Underground Explosions 682 Underground Structures	hnique nse 754	s 1195 1885	936 46 936	187			Variational M 430 851 V-Belts Vehicle Whe 130 Vibrating Str 931	Methods els ructures	974				1338	899
Unbalanced Mass Responsible 190 621 892 641 1051 1891 Underground Explosions 682 Underground Structures 60 61	hnique nse 754	s 1195 1885	936 46	187			Variational M 430 851 V-Belts Vehicle Whe 130 Vibrating Str 931	Methods els ructures bsorbers		1835 995	1216		1338	899
Unbalanced Mass Responsible 190 621 892 641 1051 1891 Underground Explosions 682 Underground Structures 60 61 981	hnique nse 754	s 1195 1885	936 46 936	187			Variational M 430 851 V-Belts Vehicle Whe 130 Vibrating Str 931	Methods els ructures		1835 995	1216	ent)	1338	899
Unbalanced Mass Responsible 190 621 892 641 1051 1891 Underground Explosions 682 Underground Structures 60 61	hnique nse 754	s 1195 1885 985 45 395	936 46 936	187	1748		Variational M 430 851 V-Belts Vehicle Whe 130 Vibrating Str 931	Methods els ructures bsorbers Vibration	Absorpt	1835 995 ion (Ed	1216	ent)	1338	899
Unbalanced Mass Response 190 621 892 641 1051 1891 Underground Explosions 682 Underground Structures 60 61 981	hnique 1se 754	985 985 45 395 1245	936 46 936 986	187		767-906	Variational Market Vehicle Whe 130 Vibrating Strans 931 Vibration Aluse Vibration Aluse	Methods els ructures bsorbers Vibration	Absorpt Equipme	1835 995 ion (Ea	1216 quipme 1836			899
Unbalanced Mass Responded 190 621 892 641 1051 1891 Underground Explosions 682 Underground Structures 60 61 981 Underwater Explosions	hnique 1se 754	985 985 45 395 1245	936 46 936 986	187			Variational Market Vehicle Whe 130 Vibrating Strans 931 Vibration Aluse Vibration Aluse	Methods els ructures bsorbers Vibration A	Absorpt Equipme	1835 995 ion (Ea	1216 quipme 1836			899 619

Vibration Absorption (Materials) 1102	Vibration Response 80 701 192 583 684 1065 6 557 608 929 410 851 552 643 824 746 627 838
Vibration Analyzers 1271	410 851 552 643 824 746 627 838 600 961 832 663 687 1558 1070 991 1292 863 787 1140 1141 1442 1073 827
Vibration Control 130 101 62 63 284 15 16 847 1499 140 883 1204 395 736 1207 1509	1792 1343 1117 1823 1817
1070 1353 475 1256 1589 1470 1363 855 1446 1373 1665 1516	Vibration Severity 1416
Vibration Dampers	Vibation Signatures 952 1413 644 1262
Vibration Damping	Vibration Source Identification
1330 981 1253 475 806 1047 1249 966 1887	456
1366 Vibration Effects	Vibration Spectra use Vibration Response Spectra
1341 1342 456 1427 408	Vibration Tests
1398	20 761 72 73 14 735 276 97 258 359 550 1421 832 683 1434 896 1349
Vibration Excitation 1491 1452 403 144 145 146 638 399 1652	1420 1431 882 1423 1376 1639 1510 1422 1646
Vibration Frequencies	Vibrators (Machinery) 346 1697
Vibration Isolation 1154 475 867	Vibratory Conveyors use Vibrators (Machinery) or Materials Handling Equipment
Vibration Isolators 870 1862 1863 465 1496 1028 1159 1495	Vibratory Techniques
Vibration Measurement 70 15 1486 457 538	Vibratory Tools 1860
90 75 1268 140 1295 1555	Violins
1605	Viscoelastic Core-Containing Media 1796
Vibration Prediction 1790 1724	1790
Vibration Reduction use Vibration Control	Viscoelastic Damping 900 494 535 1758 534
Vibration Resonance use Natural Frequencies	Viscoelastic Media
Abstract Numbers: 1-194 195-376 377-498 499-630 631-766 767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10	
<u>Issue: 1 2 3 4 5 6</u>	7 8 9 10 11 12

Viscoelastic Properties 153 293	324 1615 844	967	109 1309	Waveguide Analysis 528 1378
Viscoelasticity	1066	5		Wave Number use Frequency
Viscoelasticity Theory 662				Wave Propagation 940 41 662 803 994 776 57 928 919
Viscoplastic Properties 1750 1601	1585			1230 961 932 1553 1574 939 1121 1172 1573 1572 1582
Viscous Damping 40 951 242 1252	1104	183	8	1812 Weapons Effects
				55 56
Vortex-Induced Vibration	n 246 966			Weapons Systems 653 54 1807 48 358
Vortex Shedding 1810				Wear 254 827
Vulnerability	54	·		Wedges 712 963 406
	- W -			Wheels 1893 1835
Walls				Wheelse
710 1832 1323 1643		1627 12	8 709	Wheelset 880 169
1833				Wheel Shimmy 1016
Water Hammer		987 98	o	
Water Waves		701 70	J	Whirling 491 1752 874 1885 486 488
1762	764	757 1107	1579	. 618 1358
				Wiener-Hopf Technique
Wave Analyzers 1262	1275			961
Wave Attenuation		92	B 9 89	Wind-Induced Excitation 300 451 682 243 244 335 676 127 498 400 591 862 733 1105 1256 647 1188
Wave Diffraction 660 1232 1233	1385 1386	;		450 1481 1173 1485 1857 1438 580 1641 1330
Wave Equation	105			Windmills 647
Abstract	195			041
Abstract Numbers: 1-194 195-376 Volume 10	377-498 499-630	631-766	767-906	907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Issue: 1 2	3 4	5	6	7 8 9 10 11 12

Wind Tunnels

1488

Wind Tunnel Tests

1020 451 524 255 676 337 678 349

1650 1481 . 604 275 896 517 1651 724 1045 1237 1357

Wind Turbines

320 1122 353

Windows

127

Wing Stores

724 725 136 927 1328 859

726

Winkler Foundations

81 1616

Wire

1359

1569

Wobble

1053

Abstract
Numbers: 1-194 195-376 377-498 499-630 631-766 767-906 907-1057 1058-1208 1209-1363 1364-1516 1517-1699 1700-1896
Volume 10

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS ABBI	REVIATION
ACTA MECHANICA Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Acta. Mech.	AMERICAN SOCIETY OF MECHANICAL ENGINEERS, TRANSACTIONS United Engineering Center 345 East 47th St. New York, NY 10017	
ACUSTICA S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1 W. Germany	Acustica	JOURNAL OF APPLIED MECHANICS	J. Appl. Mech., Trans. ASME
AERONAUTICAL JOURNAL Royal Aeronautical Society 4 Hamilton Place London, W1V 0BQ, UK	Aeronaut. J.	JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME
AERONAUTICAL QUARTERLY Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. Quart.	JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engr. Indus. Trans. ASME
AIAA JOURNAL American Institute of Aeronautics and Astronautics	AIAA J.	JOURNAL OF ENGINEERING FOR POWER	J. Engr. Power, Trans. ASME
1290 Avenue of the Americas New York, NY 10019		JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech. Trans. ASME
AMERICAN SOCIETY OF CIVIL ENGING PROCEEDINGS Publications Office, ASCE United Engineering Center 345 East 47th St.	NEERS,	APPLIED ACOUSTICS Applied Science Publishers, Ltd. Ripple Road, Barking Essex, UK	Appl. Acoust.
New York, NY 10017 JOURNAL OF ENGINEERING MECHANICS DIVISION	ASCE J., Engr. Mech. Div.	APPLIED MATHEMATICAL MODELING IPC House 32 High St., Guildford Surrey GU1 3EW, UK	Appl. Math. Modeling
JOURNAL OF ENVIRONMENTA ENGINEERING DIVISION	AL ASCE J., Environ. Engr. Div.	ARCHIVE FOR RATIONAL MECHANICS AND ANALYSIS Springer-Verlag, New York, Inc. 175 Fifth Ave.	Arch. Rational Mech. Anal.
JOURNAL OF GEOTECHNICAL ENGINEERING DIVISION	ASCE J., Geotech. Engr. Div.	New York, NY 10010 ARCHIVES OF MECHANICS (ARCHIWUM MECHANIKI STOSOWANEJ)	Arch. Mech.
JOURNAL OF HYDRAULICS DIVISION	ASCE J., Hydraulics Div.	Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Stosowanej
JOURNAL OF IRRIGATION AND DRAINAGE DIVISION	D ASCE J., Irrigation Drainage Div.	ASTRONAUTICS AND AERONAUTICS AIAA EDP 1290 Avenue of the Americas New York, NY 10019	Astronaut. & Aeronaut.
JOURNAL OF STRUCTURAL DIVISION	ASCE J., Struc. Div.	AUTOMOBILTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Abteilung Technik	Automo- biltech. Z.
JOURNAL OF TRANSPORTATION ENGINEERING DIVISION	ON ASCE J., Transport. Engr. Div.	7000 Stuttgart 1, Pfizerstrasse 5-7 W. Germany	
AMERICAN SOCIETY OF LUBRICATIONS	NG ASLE, Trans.	AUTOMOTIVE ENGINEER P. O. Box 24, Northgate Ave. Bury St., Edmunds Suffolk IP32 GBW, UK	Auto. Engr.
Academic Press 111 Fifth Ave. New York, NY 10019		BALL BEARING JOURNAL (English Edition SKF (U.K.) Ltd. Luton, Bedfordshire LU3 1JF, UK) Ball Bearing J.

PUBLICATION AND ADDRESS ABB	BREVIATION	PUBLICATION AND ADDRESS ABE	BREVIATION
BAUINGENIEUR S. Hirtzel Verlag, Postfach 347 D-700 Stuttgart 1, W. Germany	Bauingenieur	EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P. O. Box 277 Westport, CT 06880	Exptl. Mech.
BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boverí Rev.	FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, W. Germany	Forsch. Ingenieurw.
BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES Ars Polona-Ruch 7 Krokowskie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.	HEATING/PIPING/AIR CONDITIONING Circulation Dept. 614 Superior Ave. West Cleveland, OH 44113	Heating/ Piping/ Air Cond.
BULLETIN OF THE FACULTY OF ENGINEERING, YOKAHAMA NATIONAL UNIVERSITY Yokahama National University OHKA-MACHI, Minami-ku	Bull. Fac. Eng. Yokahama Natl. Univ.	HIGH-SPEED GROUND TRANSPORTATION JOURNAL Planning Transportation Assoc., Inc. P. O. Box 4824, Duke Station Durham, NC 27706	High-Speed Ground Transp. J.
Yokahama, Japan BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS	Bull. JSME	HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
Japan Society of Mechanical Engineers Sanshin Hokusei Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan		HYDRAULICS AND PNEUMATICS Penton/IPC, Inc. 614 Superior Ave., West Cleveland, OH 44113	Hydraulics & Pneumatics
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826 Berkeley, CA 94705	Bull. Seismol. Soc. Amer.	IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
CHEMICAL PROCESSING Putnam Publishing Co. 430 N. Michigan Ave. Chicago, IL 60611	Chem. Processing	INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
CIVIL ENGINEERING (NEW YORK) ASCE Publications Office 345 E. 47th St. New York, NY 10017	Civ. Engr. (N.Y.)	INGENIEUR-ARCHIV Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Ing, Arch.
CLOSED LOOP MTS Systems Corp. P. O. Box 24012 Minneapolis, MN 55424	Closed Loop	INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminister, London SW1, UK	Instn. Mech. Engr. Proc.
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers Struc.	INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS Instrument Society of America 400 Stanwix St.	ISA Trans.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Des. News	Pittsburgh, PA 15222 INTERNATIONAL JOURNAL OF CONTROL	Intl. J. Control
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P. O. Box 7406 Milwaukee, WI 53213	Diesel Gas Turbine Prog.	Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK INTERNATIONAL JOURNAL OF	Intl. J.
MINBURCE, WI 90210		EARTHQUAKE ENGINEERING	Earthquake

EARTHQUAKE ENGINEERING

John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016

AND STRUCTURAL DYNAMICS

Dynam.

Earthquake

Engr. Struc.

ENGINEERING MATERIALS AND DESIGN Engr. Matl.
IPC Industrial Press Ltd. Des.
33-40 Bowling Green Lane
London EC1R, UK

PUBLICATION AND ADDRESS ABBR	REVIATION	PUBLICATION AND ADDRESS ABO	BREVIATION
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engr. Sci.	JOURNAL OF THE AMERICAN HELICOPTER SOCIETY American Helicopter Society, Inc. 30 E. 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Pergamon Press, Inc. Maxwell House, Fairveiw Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.	JOURNAL OF COMPOSITE MATERIALS Technomic Publishing Co., Inc. 750 Summers St. Stamford, CT 06901	J. Composite Matl.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.	JOURNAL OF ENGINEERING MATHEMATICS Academic Press 198 Ash Street Reading, MA 01867	J, Engr. Math.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlin. Mech.	JOURNAL OF ENVIRONMENTAL SCIENCES Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engr.	JOURNAL OF FLUID MECHANICS Cambridge University Press 32 East 57th St. New York, NY 10022	J. Fluid Mech.
INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS John Wiley and Sons, Ltd. Baffins Lane Chichester, Sussex, UK	Intl. J. Numer. Anal. Methods Geomech.	JOURNAL OF THE FRANKLIN INSTITUTE Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES Pergamon Press, Inc. Maxwell House, Fairview Park	Intl. J. Solids Struc.	JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA Science House, 157 Gloucter Sydney, Australia 2000	J. Inst. Engr., Australia
Elmsford, NY 10523 ISRAEL JOURNAL OF TECHNOLOGY Weizmann Science Press of Israel Box 801	Israel J. Tech.	JOURNAL OF MECHANICAL ENGINEERING SCIENCE Institution of Mechanical Engineers 1 Birdcage Walk, Westminister London SW1 H9, UK	J. Mech. Engr. Sci.
Jerusalem, Israel JOURNAL DE MÉCANIQUE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique	JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mech. Phys. Solids
JOURNAL DE MÉCANIQUE APPLIQUÉE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique Appl.	JOURNAL OF PHYSICS E. (SCIENTIFIC INSTRUMENTS) American Institute of Physics 335 East 45th St. New York, NY 10017	J. Phys. E. (Sci. Instr.)
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.	JOURNAL OF SHIP RESEARCH Society of Naval Architects and Marine Engineers 20th and Northhampton Sts. Easton, PA 18042	J. Ship Res.
JOURNAL OF AIRCRAFT American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Aircraft	JOURNAL OF SOUND AND VIBRATION Academic Press 111 Fifth Ave. New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS ABB	REVIATION	PUBLICATION AND ADDRESS ABB	REVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics	J. Space- craft Rockets	MTZ MOTORTECHNISCHE ZEITSCHRIFT Frankh'sche Verlagshandlung Pfizerstrasse 5-7 7000 Stuttgart 1, W. Germany	MTZ Motor- tech. Z.
1290 Avenue of the Americas New York, NY 10019 JOURNAL OF TESTING AND EVALUATION (ASTM)	J. Test Eval.	NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bidg. 1012 - 14th St., N.W.	Naval Engr. J.
American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103		Washington, D.C. 20005 NOISE CONTROL VIBRATION ISOLATION Trade and Technical Press Ltd.	Noise Control Vib.
KONSTRUKTION Springer Verlag 3133 Connecticut Ave., N.W. Suite 712	Konstruktion	Crown House, Morden Surrey SM4 5EW, UK	Isolation Noise
Washington, D.C. 20008 LUBRICATION ENGINEERING	Lubric.	NOISE CONTROL ENGINEERING P. O. Box 2167 Morristown, NJ 07960	Control Engr.
American Society of Lubrication Engineers 838 Busse Highway	Engr.	NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS,	NE Coast Instn. Engrs.
Park Ridge, IL 60068 MACHINE DESIGN	Mach. Des.	TRANSACTIONS Bolbec Hall, Newcastle Upon Tyne 1, UK	Shipbldrs., Trans.
Penton Publishing Co. Penton Bldg. Cleveland, OH 44113		NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P. O. Box 3489	Nucl. Engr. Des.
MASCHINENBAUTECHNIK VEB Verlag Technik	Maschinen- bautechnik	Amsterdam, The Netherlands	
Oranienburger Str. 13/14 102 Berlin, E. Germany		OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne	Oil Gas J.
MECCANICA Pergamon Press, Inc.	Meccanica	Tulsa, OK 74101	
Maxwell House, Fairview Park Elmsford, NY 10523		OSAKA UNIVERSITY, TECHNICAL REPORTS Faculty of Technology	Osaka Univ., Tech. Rept.
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 E. 45th St.	Mech. Engr.	Osaka University Miyakojima, Osaka, Japan	
New York, NY 10017 MECHANICAL ENGINEERING,	Instn. Mech.	PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engr.
TRANSACTIONS, THE INSTITUTION OF ENGINEERS, AUSTRALIA	Engr., Australia,	PHYSICS TODAY	Physics
The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600	Mech. Engr. Trans.	American Institute of Physics, Inc. 335 East 45th St. New York, NY 10017	Today
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press, Inc.	Mech. Res. Comm.	POWER P. O. Box 521 Hightston, NJ 08520	Power
Maxwell House, Fairview Park Elmsford, NY 10523		POWER TRANSMISSION DESIGN Industrial Publishing Co.	Power Transm. Des.
MECHANISM AND MACHINE THEORY Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory	Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engr. Kyoto Univ.	PRODUCT ENGINEERING (NEW YORK) McGraw-Hill Book Co. P. O. Box 1622 New York, NY	Product Engr. (NY)
MEMOIRES OF THE FACULTY OF ENGINEERING, NAGOYA UNIVERSITY Library, Nagoya University Furo-Cho, Chikusa-ku Nagoya, Japan	Mem. Fac. Engr. Nagoya Univ.	QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mech. Appl. Math.

PUBLICATION AND ADDRESS ABE	REVIATION	PUBLICATION AND ADDRESS A	ABBREVIATION
REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MÉCANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumanie 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mécanique	TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA Instrument Society of America 400 Standix St. Pittsburgh, PA 15222	Instr. Soc. Amer.
REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.	TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.
SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.	VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, Germany	VDI Z.
SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.	VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied	SIAM J. Numer. Anal.	VIBROTECHNIKA Kauno Polytechnikos Institutas Kaunas, Lithuania	Vibro- technika
Mathematics 33 S. 17th St. Philadelphia, PA 19103		WEAR Elsevier Sequoia S.A. P. O. Box 851	Wear
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS	Soc. Naval Arch. Mar. Engr., Trans.	1001 Lausanne 1, Switzerland	
Society of Naval Architects and Engineers 20th and Northhampton St. Easton, PA 18042		ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepziger Str. 3-4 108 Berlin,	Z. angew. Math. Mech.
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviat Rd. Bay Village, OH 44140	S/V, Sound Vib.	Germany ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR	Z. Flugwiss
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen	D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	

ANNUAL PROCEEDINGS SCANNED

INTERNATIONAL CONGRESS ON ACOUSTICS, ANNUAL PROCEEDINGS	Intl. Cong. Acoust., Proc.	THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway	Inst. Environ. Sci., Proc.	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375	Lao., Proc.
Mt. Prospect, IL 60056		UNITED STATES CONGRESS ON APPLIED MECHANICS. ANNUAL	U.S. Cong. Appl. Mech.,
MIDWESTERN CONFERENCE ON SOLID MECHANICS, ANNUAL	Midw. Conf. Solid Mech.	PROCEEDINGS	Proc.
PROCEEDINGS	Proc.	WORLD CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	World Cong. Appl. Mech., Proc.

CALENDAR

DECEMBER 1978

- 4-6 15th Annual Meeting of the Society of Engineering Science, Inc., [SES] Gainesville, FL (Prof. R.L. Sierakowski, Div. of Continuing Education, Univ. of Florida, 2012 W. University Ave., Gainesville, FL 32603)
- 10-15 Winter Annual Meeting, [ASME] San Francisco, CA (ASME Hq.)
- 11-14 Truck Meeting, [SAE] Hyatt Regency, Dearborn, MI (SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096)

FEBRUARY 1979

26-Mar 2 Congress & Exposition, [SAE] Cobo Hall, Detroit, MI (SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)

APRIL 1979

- 30-May 2 NOISE-CON 79, [INCE] Purdue University, IN (NOISE-CON 79, 116 Stewart Center, Purdue University, West Lafayette, IN 47907 Tel. (317) 749-2533)
- 30-May 2 Environmental Sciences Meeting, [IES] Seattle, WA (Dr. Amiram Roffman, Energy Impact Assoc., Inc., P.O. Box 1899, Pittsburg, PA 15230 Tel. (412) 256-5640)
- 30-May 3 1979 Offshore Technology Conference, [ASME] Astrodomain, Houston, TX (ASME Hq.)

MAY 1979

20-25 Spring Meeting and Exposition, [SESA] San Francisco, CA (SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)

JUNE 1979

12-16 Acoustical Society of America, Spring Meeting, [ASA] Cambridge, MA (ASA Hq.)

SEPTEMBER 1979

10-12 ASME Vibrations Conference, [ASME] St. Louis, MO., (ASME Hq.)

- 10-13 Off-Highway Meeting and Exposition, [SAE] MECCA, Milwaukee, WI (SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)
- 11-14 INTER-NOISE 79, [INCE] Warsaw, Poland (INTER-NOISE 79, IPPT PAN, ul. Swietokrzyska 21, 00-049 Warsaw, Poland)

OCTOBER 1979

7-11 Fall Meeting and Workshops, [SESA] Mason, OH SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)

NOVEMBER 1979

- 4-6 Diesel and Gas Engine Power Technical Conference, San Antonio, TX (ASME Hq.)
- 5-8 Truck Meeting, [SAE] Mariott, Ft. Wayne, IN (SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)
- 26-30 Acoustical Society of America, Fall Meeting, [ASA] Salt Lake City, UT (ASA Hq.)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information

Processing Societies

210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association

1330 Mass. Ave., N.W.

Washington, D.C.

AHS:

AIAA:

American Helicopter Society

1325 18 St. N.W. Washington, D.C. 20036

American Institute of Aeronautics and

Astronautics, 1290 Sixth Ave.

New York, NY 10019

AIChE: American Institute of Chemical Engineers

345 E. 47th St. New York, NY 10017

AREA: American Railway Engineering Association

59 E. Van Buren St. Chicago, IL 60605

AHS: American Helicopter Society

30 E. 42nd St.

New York, NY 10017

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America

335 E. 45th St. New York, NY 10017

ASCE: American Society of Civil Engineers

345 E. 45th St. New York, NY 10017

ASME: American Society of Mechanical Engineers

345 E. 47th St. New York, NY 10017

ASNT: American Society for Nondestructive Testing

914 Chicago Ave. Evanston, IL 60202

ASQC: American Society for Quality Control

161 W. Wisconsin Ave. Milwaukee, WI 53203

ASTM: American Society for Testing and Materials

1916 Race St.

Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,

Toronto 5, Ontario, Canada

ICF:

IEEE:

International Congress on Fracture

Tohoku Univ.

Sendai, Japan

Institute of Electrical and Electronics Engineers

345 E. 47th St.

New York, NY 10017

IES: Institute of Environmental Sciences

940 E. Northwest Highway Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of

Machines and Mechanisms, US Council for

TMM, c/o Univ. Mass., Dept. ME

Amherst, MA 01002

INCE: Institute of Noise Control Engineering

P.O. Box 3206, Arlington Branch

Poughkeepsie, NY 12603

ISA: Instrument Society of America

400 Stanwix St. Pittsburgh, PA 15222

ONR: Office of Naval Research

Code 40084, Dept. Navy Arlington, VA 22217

SAE: Society of Automotive Engineers

400 Commonwealth Drive Warrendale, PA 15096

SEE: Society of Environmental Engineers

6 Conduit St.

London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis

21 Bridge Sq. Westport, CT 06880

SNAME: Society of Naval Architects and Marine

Engineers, 74 Trinity PI. New York, NY 10006

SPE: Society of Petroleum Engineers

6200 N. Central Expressway

Dallas, TX 75206

SVIC: Shock and Vibration Information Center

Naval Research Lab., Code 8404

Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - US

National Committee c/o MIT Lincoln Lab.,

Lexington, MA 02173

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY, CODE 8404 SHOCK AND VIBRATION INFORMATION CENTER Washington, D.C. 20375

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, \$300.
THIRD CLASS MAIL

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DoD-316



THE SHOCK AND VIBRATION DIGEST

Volume	10, No. 12	·	December 1978
EDITOR:	IAL .	36	Annual Article Index
		39	Book Reviews
1	Director Notes	42	Book Reviews: 1978
2	Editors Rattle Space		
ARTICLI	ES AND REVIEWS	CURREN	NT NEWS
		45	Short Courses
3	Feature Article - SHOCK AND VIBRATION ANALYSIS USING	48	News Briefs
	FINITE ELEMENT TECHNIQUES T.V. Seshadri	ARSTR A	CTS FROM THE CURRENT
e e e	1.V. Sesnauri		RATURE
10	Literature Review	4	
		49	Abstract Categories
11	A SKETCH OF AEROACOUSTICS	50	Abstract Contents
	R.E.A. Arndt	51	Abstracts: 78-1700 to 78-1896
		96	Annual Author Index
21	RECENT RESEARCH IN PLATE	115	Annual Subject Index
	VIBRATIONS. 1973-1976: COM-	155	Periodicals Scanned
	PLICATING EFFECTS A.W. Leissa	CALEND	AR